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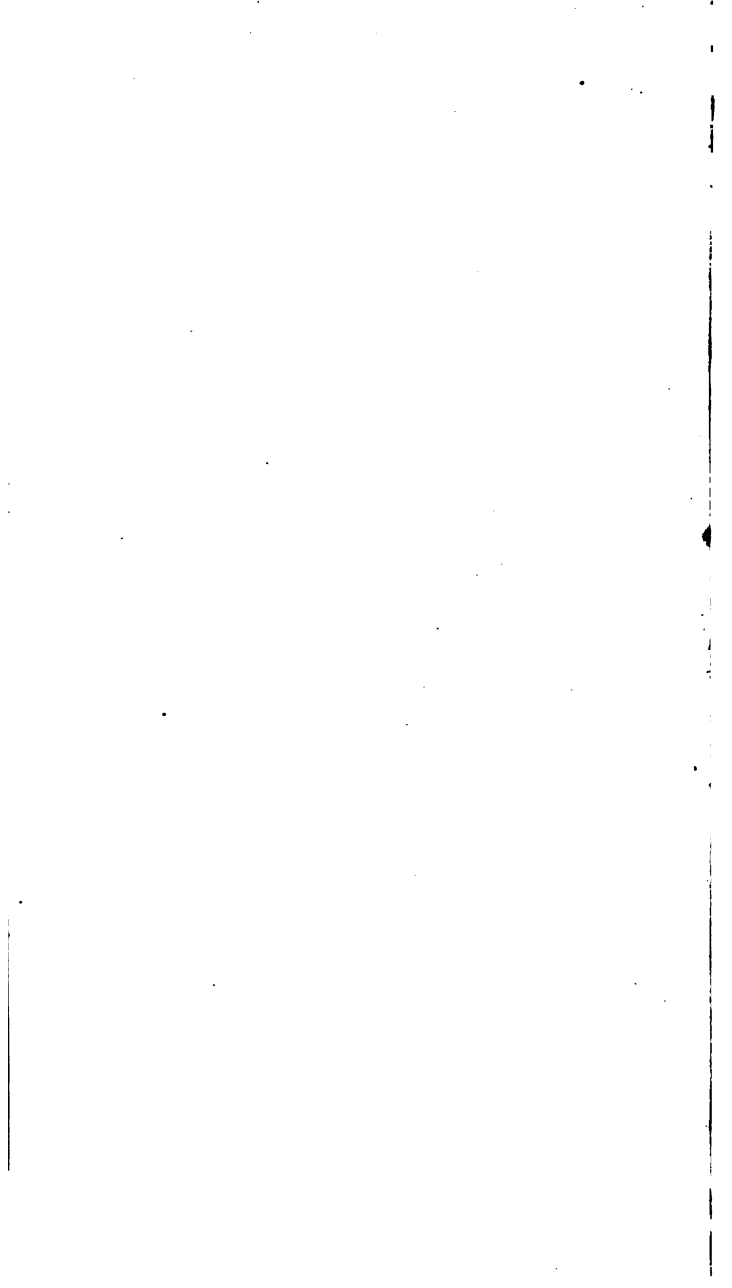
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FOR
CIVIL ENGINEERS
CARHART

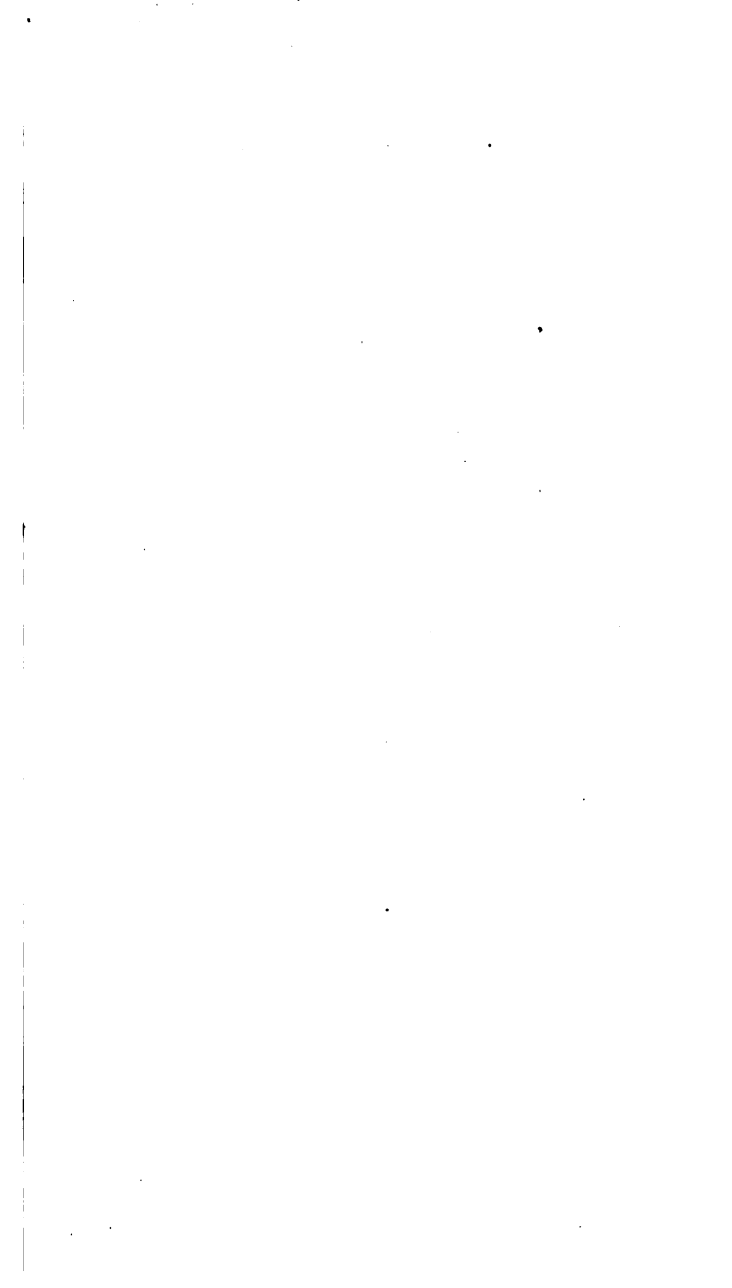
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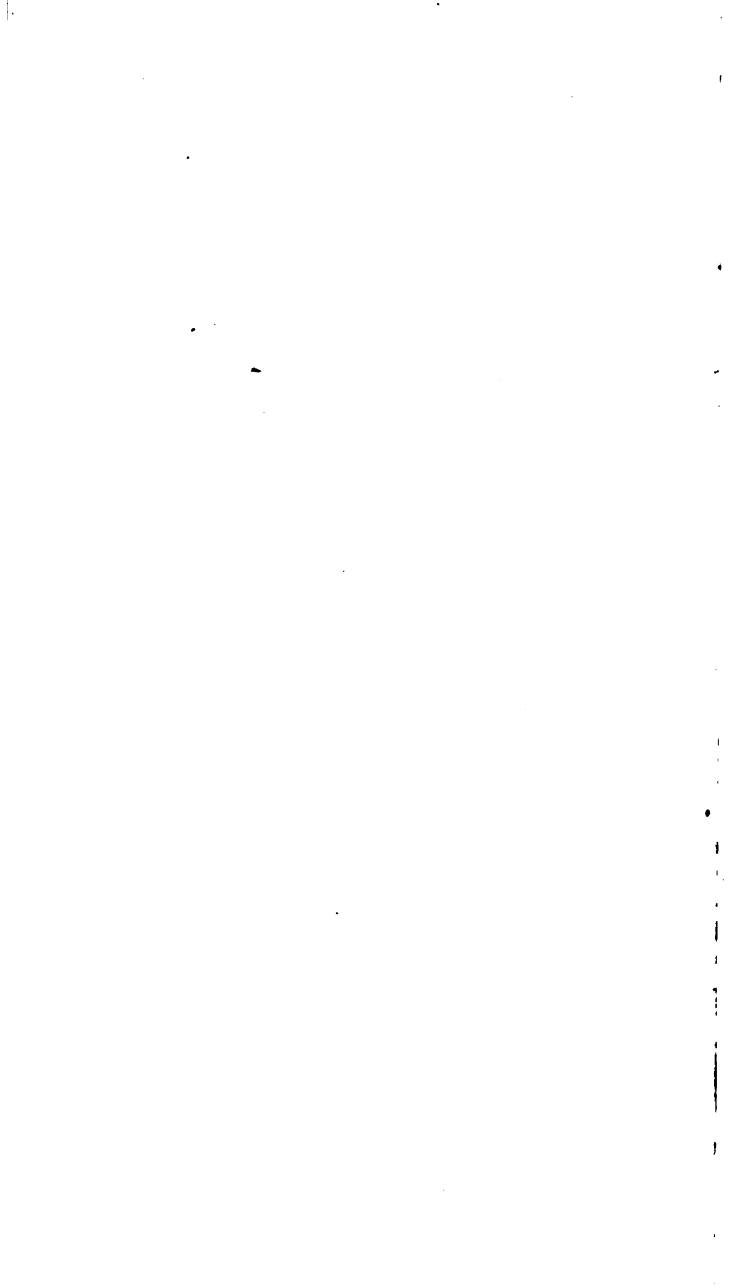
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A
FIELD BOOK

FOR
CIVIL ENGINEERS.

BY
DANIEL CARHART, C.E.,
DEAN AND PROFESSOR OF CIVIL ENGINEERING IN THE WESTERN
UNIVERSITY OF PENNSYLVANIA.



BOSTON, U.S.A.:
GINN AND COMPANY.
1903.

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PREFACE.

THE work of the Civil Engineer is varied and extensive. He may be called upon to survey a tract of land ; to lay out a town ; plan a system of water supply, and sewerage ; to locate and construct a road, canal or railroad ; to design and erect a bridge, or roof ; to build a light-house ; improve the regimen of a water course ; maintain a highway in good condition ; in fact, several of these pages would be necessary to even enumerate the requirements which the modern engineer is expected to meet, and almost every topic would furnish material for a manual. In this book it is proposed to treat that part of the Civil Engineer's work which will enable him to locate the center line of a railroad ; to set the stakes incident to its construction ; to compute the quantities ; and to solve the problems pertaining to track laying.

The book is written for students of civil engineering, and to satisfy a demand, often expressed by field engineers, for a manual convenient in size, containing the desired information, systematically arranged, fully illustrated, and easy of reference

It abounds in problems, such as are likely to arise in ordinary field practice, accompanied by full explanations, and with illustrative examples wherever it seems at all necessary.

The arrangement of the matter is the natural one ; in other words, the various subjects are introduced and treated in the order in which they present themselves in actual work. Accordingly reconnoissance, preliminary survey and location, with the required instruments, occupy the first two chapters. In Chapters III. and IV. there are numerous formulas derived,

practical problems proposed, and solutions indicated for them in connection with running simple and compound curves, which are supplemented in Chapter V. by a set of miscellaneous questions, among which several forms of the Y problem are discussed.

Chapter VI. treats of construction, consequently here, among other things, are introduced methods of setting out the work and computing quantities. The difficulties which the young engineer experiences in setting slope stakes, were kept vividly in mind when writing this chapter. It is believed that the subject is presented in such a simple manner, and so fully illustrated, that he can easily comprehend it, and make ready use of the methods explained.

Chapter VII., on Frogs and Switches, is from the pen of my esteemed friend and former student, Lewis C. Weldin, C. E., Assistant Engineer Pennsylvania Railroad. Mr. Weldin's twenty years' experience in the engineering department of this famous highway, qualifies him to present, with the authority of an expert, this subject in a most practical manner. By adopting a notation slightly different from that of other writers under this head, he has, in many cases, obtained results much simpler than any hitherto published, and he has increased the value of his work by the introduction of numerous formulas and examples, selected from his extensive practice. I therefore desire to express here my acknowledgments to Mr. Weldin for this valuable chapter.

The book contains all the necessary tables for field use. Among them are included tables of natural trigonometric functions, sines, cosines, secants, cosecants, tangents, cotangents, versed sines, and exsecants, as well as tables of radii, long chords, squares, cubes, functions of a one-degree curve, and numerous others. The author believes that time is saved by

using, in the field, the natural instead of the logarithmic trigonometric functions; accordingly he has omitted the long tables, usually found in field books, of logarithmic sines, tangents, etc. A table of logarithms of numbers, however, is inserted. The sines, cosines, secants and cosecants, are on tinted paper, and placed near the middle of the set of tables. All others are on white paper; tangents, versed sines, and exsecants, near the end, and logarithms of numbers, radii, long chords, etc., near the beginning of the set. Thus the tinted pages indicate plainly where four important tables may be found, as well as favor the eye while reading thereon, and with a little familiarity, soon acquired, as to the relative position of others, a person can quickly turn to any one which he may need.

Besides the introduction of tinted paper, there will be noticed, for the first time in a field book, the absence of vertical lines in some of the tables, and the consequent facility and ease with which these pages can be consulted, will doubtless be remarked.

In submitting this work to the profession, the author trusts that it will prove helpful to the student of civil engineering in acquiring a knowledge of field practice, and useful to the young practitioner in pursuing his profession, as well as a convenient and reliable work of reference to all who use engineering instruments in the field. With such results accomplished, his aim will be attained.

D. C.

SEPTEMBER, 1893.

NOTE.

AT the earnest solicitation of those who make use of the book both in office and field work, Tables XX and XXI of the logarithms of trigonometric functions have been added. These tables were printed from electrotypes from Nagle's "Field Manual for Railroad Engineers." Also, a growing demand for some method, easily applied, to pass from tangent to curve or *vice versa* will be met, it is believed, by an Appendix on the Transition Curve. My acknowledgments are due and are hereby made to W. C. Armstrong, Bridge Engineer of the Chicago and Northwestern Railway, for permission to use matter from his publications for this Appendix. His method will be found extremely simple as regards both elucidation and application.

D. C.

JANUARY 3, 1903.

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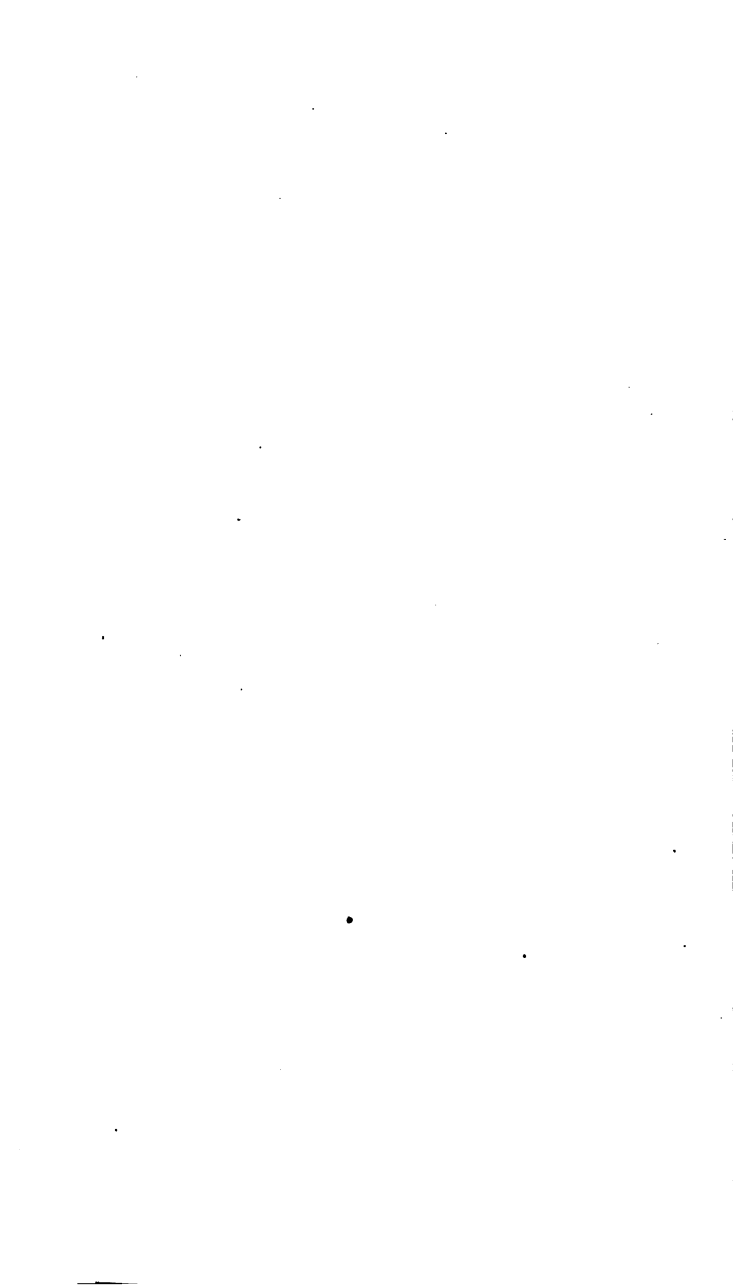
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ERRATA.

PAGE

57. In first part of example at bottom, $\cot 17^\circ$ was used instead of 16° , causing an error of one minute in degree of curve.
65. Tenth line from bottom, for *off* read *of*.
68. The letter *A* is wanting in the figure at end of line *DP*.
69. Fifth line from top, *E* should be *E*₁.
74. In the figure the upper *T* should be *T'*.
81. In eighth line from bottom, for *radii* read *radius*.
81. *a* in ninth line from bottom should be *a'*.
83. In last line, for *PD* read *PP'*.
85. In Fig. 49 the *O* at the *right-hand angle* should be *O'*.
93. Right-hand member of eq. (90) should read $2 R' \sin \frac{1}{2} EOD$.
94. Second line from bottom, the first *DT* should be *TT'*.
95. First equation should read $R' = \frac{cc''}{2d}$.
96. Eleventh line from bottom, for *affected* read *effected*.
98. Seventeenth line from top should have — before $\frac{1}{2} x$.
116. Third line from bottom, for $\frac{12}{6}$ read $\frac{12}{2}$.
119. Fourth line from bottom, for *PCP* read *PCP'*.
120. Middle term in tenth line from top should read
$$\frac{2}{3} \left[\frac{1}{2} (d - d') + d' \right].$$
120. Fifth line from bottom, *bGE* should be *CGE*.
121. Second line from top, for $\frac{0}{1\frac{1}{4}}$ read $\frac{14}{0}$.
121. Third line from top, for $\frac{0}{10}$ read $\frac{10}{0}$.
121. Fourth line from top, for $\frac{0}{1\frac{1}{2}}$ read $\frac{12}{0}$.
121. Sixth line from top should read, between equality signs, $\frac{1}{27} (746 + 2180 + 370) \frac{100}{0}$.
144. Third line from bottom, for $\sin F$ read $\sin F'$.
147. Eleventh line from bottom, for *C* read *B*.
148. First member of eq. (145) should be *ED*.
152. In Fig. 93 there should be a *B* at intersection of lines *KD* and *AR*.
153. In eqs. (160) and (161), for 360 read 180.
155. In eqs. (165) and (166), for 360 read 180.
156. In eqs. (171) and (172), for 360 read 180.
157. In eq. (173), for *O'O* read *O''O*.
216. Opposite the cosine $18^\circ 57'$, for 93580 read 94580.





FIELD BOOK.

CHAPTER I.

RECONNOISSANCE.

1. In determining the best location for any highway, especially if it is to be of considerable length, it is customary for the engineer to make a hasty examination of the country lying in the general direction of the proposed route ; gathering facts regarding streams, mountains, valleys, soil, etc., and other data bearing upon the construction of the highway, the business it may command, and the cost of operating it, seeking thereby to limit and minimize the detailed work which follows. Such examination is called a *Reconnaissance*.

2. **The Instruments** which may be used advantageously on such surveys, are the pocket compass, Locke level, tape measure, aneroid barometer, and field-glass.

a. The Pocket Compass may be used for roughly determining the direction of any line.

b. The Locke Level for obtaining approximately the difference in height of two points by direct measurement, where the points are not far apart, either vertically or horizontally.

c. The Aneroid Barometer may be used to determine quite closely the difference in elevation of two places whose distance in any direction may be considerable, in the following manner :

Take the barometric reading at each station ; denote the reading at the lower and upper station respectively by b and b' , and the required difference in feet by d .

Then $d = 60300 (\log b - \log b')$.

EXAMPLE.

If the reading of the barometer at the foot of a mountain be 28.5 inches, and at the top, 26 inches, the height of the mountain will be

$$d = 60300 (\log 28.5 - \log 26) = 2404 \text{ feet.}$$

3. In preparing to make a reconnoissance, the engineer should also provide himself, if he can, with a good map of the locality to be traversed, and, as far as possible, obtain from persons acquainted with the country information pertaining to the case in hand. From a map he will perceive the direction, length, and location of the water courses and their tributaries, the position of mountains, valleys, etc. He will ascertain upon inquiry something concerning "high" and "low" water, the behavior of streams during floods, ice gorges, maximum snow fall, etc.

4. Ordinarily in making a railroad along a river, bridges have to be built to span tributaries. If the *divide* is kept,

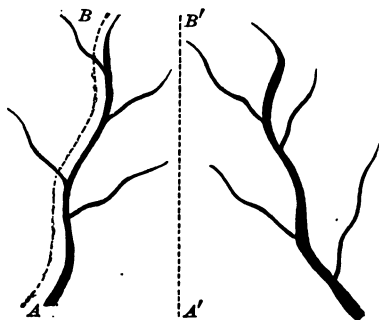


FIG. 1.

few, if any, bridges will be necessary, as may be seen in the figure opposite, where AB represents the line near bank of stream, and $A'B'$ that on the dividing ridge between two valleys or streams. To pass from the valley of one water-course to another it is sometimes practicable to do so with easy grades,

where their sources are quite near together, by following up one and crossing the ridge by cut or tunnel, gaining the other as CED . To go directly across from C to D would generally involve considerable earth work, or heavier grades, though there would be a saving in distance. The items of bridges,

however, on tributaries, grades, cost of earth work, and business to be acquired on the different lines, as well as the maintenance of the permanent way and other operating expenses, must have great weight in deciding the route.

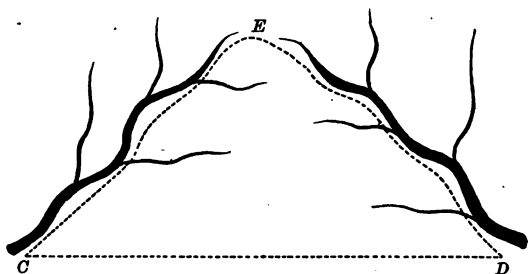


FIG. 2.

5. Having studied carefully the maps, and obtained all information possible from other available sources, the engineer proceeds to traverse the country in both directions, observing its topography, nature of the soil, banks, beds, and accessibility of rivers; and objective points, such as passes in mountains to be crossed, and depressions in ridges through which the best grade may be secured, adding to his knowledge already acquired, and thereby qualifying himself for an intelligent decision in the matter of location.

The young engineer will gain much general information bearing on this subject by careful examination of some existing lines traversing our country, especially will he be benefited by a study of the history and location of our trans-continental lines.

CHAPTER II.

PRELIMINARY SURVEY.

6. **A Preliminary Survey** is an examination in detail of the belt of country somewhere in which the location of the line is likely to be made; the data for determining its limits having been obtained on the reconnoissance. The field corps required to make it may be organized into three parties as follows:—

THE TRANSIT PARTY.

THE LEVEL PARTY.

THE TOPOGRAPHIC PARTY.

A. THE TRANSIT PARTY.

7. **The Transit Party** is composed of one chief engineer or senior assistant, a transitman, two chainmen, two or more axemen, a stakeman, and a flagman.

The instruments needed by this party are the transit, two sight-poles, a hundred-foot chain or tape, and axes for the axemen.

THE TRANSIT.

The principal adjustments are

1. The Levels.
2. The Line of Collimation.
3. The Standards.

8. **To adjust the levels**, *that is, to make the level-tubes parallel to the vernier plate, or perpendicular to the axis of the instrument.*
—Set up the instrument firmly, and by the leveling screws, bring each bubble to the center of its run. Then turn the plate half-way round. The bubbles should remain centered; if they do not, then with the adjusting pin turn the small screws at the end of the level until the bubbles are moved over half the error. Then bring the bubbles again to the center by the leveling screws, and repeat the operation, if necessary, until the bubbles will remain centered during a complete revolution of the plate.

9. To adjust the line of collimation, or, *to make the line of collimation perpendicular to the horizontal axis of the telescope.* — Set up the instrument on tolerably level ground, level it, and bring the intersection of the cross-hairs on a definite point two or three hundred feet away. Clamp the plate to prevent horizontal motion, plunge the telescope, and locate a point now covered by the intersection of the cross-hairs, opposite the first and at about the same distance from the instrument. Now unclamp the limb, revolve it horizontally half-way round, and set the intersection of the cross-hairs on the point first observed. Clamp as before, and plunge the telescope again; the intersection of the cross-hairs should cover the second point set; if it do not, then with the adjusting screws at the side of the telescope, screwing one in and the other out simultaneously, move the vertical hair until it covers a point *one-fourth* the distance between the last two. Repeat the operation to check the work.

10. To adjust the standards, *that is, to make the horizontal axis of the telescope parallel to the vernier plate, or the locus of the line of sight a vertical plane.*

Set up the instrument firmly and level as before, set the intersection of the cross-hairs on some high, well-defined point, as a church spire, or some projection of a high chimney. Clamp the plates, to prevent horizontal motion, depress the object end of the telescope, and direct the intersection of the cross-hairs to a point on the ground a few feet from the instrument. Now unclamp and turn the instrument horizontally half-way round, sight the first point, clamp as before, and note if in depressing the telescope the intersection of the cross-hairs covers the lower point. If it do not, then with the adjusting screws in one of the standards, raise or lower that end of the horizontal axis until the motion of the line of sight in a vertical plane is assured. Check as before.

AUXILIARIES.

1°. *The Stadia.*

11. **The Stadia** is a compound cross-wire ring or diaphragm, shown in Fig. 3, having three horizontal wires, of which the middle one is cemented to the ring as usual, while the others, *bb* and *cc*, are fastened to small slides, held apart by a slender brass spring hoop, and actuated by independent screws *dd*, by which the distance between the two movable wires can be adjusted to include a given space; as, 1 foot on a rod 100 feet distant. These wires will in the same manner include 2 feet on a rod 200 feet distant, or half a foot at a distance of 50 feet, and so on in the same proportion; thus furnishing a means of measuring distances—especially over broken ground—much more easily, and even more accurately, than with a tape or chain.

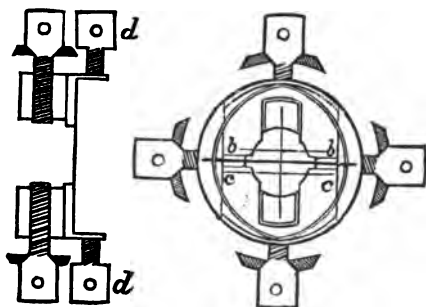


FIG. 3.

12. Its principles may be explained more fully as follows:

Let Fig. 3a represent a section of a common telescope with but two lenses, between which the diaphragm with the stadia wire is placed, and assume that

f = the focal distance of the object glass;

p = the distance of the stadia wires *a* and *b* from each other;

d = the horizontal distance of the object glass to the stadia;

a = the stadia reading (BA);

D = the horizontal distance from middle of instrument to stadia.

The Telescope is leveled and sighted to a leveling or stadia rod, which is held vertically, hence at right angles with the line of sight. According to a principle of optics, rays parallel to the axis of the lens meet, after being refracted, in the focus of the lens. Suppose the two stadia wires are the sources of those rays, we have, from the similarity of the two triangles $a'b'F$ and FAB , the proportion

$$d - f : a = f : p.$$

The quotient $f : p$ is, or at least can be made, constant, and may be designated by k , hence we may write

$$d - f = FC = ka.$$

To get the distance from the center N of the instrument there must be added to FC the value

$$c = OF + ON.$$

ON is mostly equal to half the focal length of the object glass ; hence,

$$c = 1.5f.$$

Therefore the formula for the distance of the stadia from the center of the instrument, when that stadia is at right angles to the level line of sight, is

$$D = ka + c. \quad (1)$$

13. When the line of sight is not level it is impracticable, especially in long distances, to hold the rod in a vertical plane, and at the same time perpendicular to the line of sight ; hence it is customary to hold the rod vertical, as in the preceding case, and obtain the true distance by applying a correction depending upon the angle of inclination of the sight.

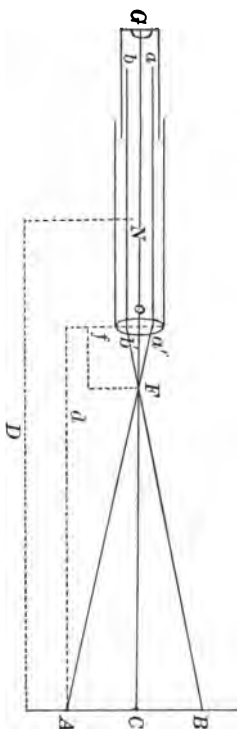


FIG. 3a.

Substituting this value of GF in the equation above, we obtain

$$a = \frac{CD \cos m [\cos (n + m) + \cos (n - m)]}{2 [\cos (n + m) \cos (n - m)]},$$

or, $CD = a \frac{\cos^2 n \cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos^2 m},$

and $D' = c + ka \frac{\cos^2 n \cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos^2 m}.$

Whence $D = c \cos n + ka \cos^2 n - ka \sin^2 n \tan^2 m.$

The third term of the second member of this equation may be safely neglected, as it is very small, even for long distances and large angles of elevation (for 1500', $n = 45^\circ$ and $k = 100$, it is but 0.07') ; therefore, the final formula for distances, with a stadia kept vertical, and with wires equidistant from the center wire, is the following : —

$$D = c \cos n + ak \cos^2 n. \quad (2)$$

The value of $c \cos n$ is usually neglected, as it amounts to but 1 or 1.5 feet ; it is exact enough to add always 1.25' to the distance as derived from the formula,

$$D = ak \cos^2 n. \quad (2a)^*$$

14. The focal length of the object-glass may be found by focussing the instrument upon some distant object, say a heavenly body, and measuring then the distance between the plane of the cross-wires and that of the objective. ON , being equal to the distance between the objective and the intersection of a plumb-line with the horizontal axis of the telescope, may be obtained by direct measurement. The distance p , between the stadia wires, may be determined as follows : —

Set up the instrument on level ground, and measure forward from the plumb-line a distance equal to c , and mark the point ; measure onward from the mark any convenient distance d , 400 or 500 feet as a base. The telescope being level, observe carefully the space a intercepted by the stadia wires on a leveling

* The above explanation of the stadia is substantially that given by Mr. G. J. Specht, published by Van Nostrand, 1884, though corrected and simplified. See Table XIX for reducing stadia measurements.

rod held vertically at the farther extremity of the base. Then from the proportion $d - f : a = f : p$, the required distance p may be obtained.

EXAMPLES.

1. Given $f = 8$ inches, base = 500 feet, and $a = 5.25$ feet. Find $p = .084$ inches.

2. At what fractional part of the focal length must the stadia wires be separated so that one foot on the rod will correspond to 100 feet base?

2°. The Gradienter.

15. The gradienter is an attachment to the transit which may be used for running grades, determining distances, etc. In its construction, a clamping arm extends downwards from the axle upon which the telescope revolves, and is forked at lower extremity to embrace a micrometer headed nut. This nut moves along a screw accurately cut, making a certain number of revolutions to the hundredth of a foot. The head of the screw is graduated into one hundred parts, and attached is a zero edge for reading the graduations.

As the proportion of the screw is such that a complete revolution gives one foot vertical in a distance of 100 feet horizontal, when the motion of the telescope measures this foot, it necessarily follows that the rod must be 100 feet distant; or if telescope measures 1.5 feet the rod must be 150 feet distant.

Hence, to run a certain gradient, bring the telescope level by means of the milled head screw, and note the reading; then continue the motion of the milled head one revolution and part thereof for each foot and part thereof, of foot per hundred of the desired gradient.

Thus, to set off a gradient of 0.5 foot per 100 feet, move micrometer milled head 50 graduations from the level.

To set off 1.25 foot per 100 feet, move one revolution and twenty-five graduations.

To measure distances, note the space on rod passed over by one revolution of the micrometer head. Thus, if one revolution of micrometer head passes from 4.2 to 5.6, the difference, 1.4, indicates the distance of rod from instrument of 140 feet.

3°. The Vernier.

16. The Vernier. Though, perhaps, it cannot be considered an auxiliary to the transit in the same sense as the preceding, it is thought best to give in this place some explanation of it, more especially for the benefit of the young engineer.

It is an auxiliary scale for measuring smaller divisions than those into which a graduated scale or limb is divided. The smallest reading of the vernier, or *least count*, is the difference in length between one division on the graduated scale or limb, and one on the vernier. If the divisions on the vernier are smaller than those on the limb, the vernier is *direct*; if the reverse, *retrograde*.

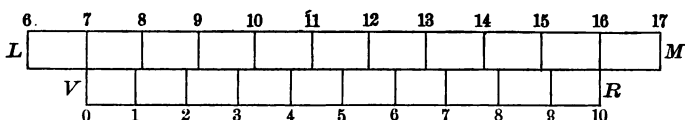


FIG. 5.

Let LM represent any scale divided into tenths, and we wish to measure or read to tenths of these divisions, i. e., to $\frac{1}{100}$.

Using a direct vernier, we should have 10 spaces on it equal to 9 on the scale, and each one of them equal to $\frac{9}{10}$ of $\frac{1}{10}$, or $\frac{9}{100}$, of the scale of graduation, giving a *least count* of $\frac{1}{100} - \frac{9}{100} = \frac{1}{100}$, as desired.

To read to twentieths of the divisions on the scale, we should have 20 divisions on the vernier corresponding to 19 on the scale, or each space on the vernier equal to $\frac{19}{20} \times \frac{1}{10} = \frac{19}{200}$, and giving a *least count* of $\frac{20}{200} - \frac{19}{200} = \frac{1}{200}$.

In general, if s = the smallest division of the scale or limb,
 v = the smallest division of the vernier,
 n = the number of divisions on the vernier,

we shall have least count $= s - v = \frac{s}{n}$.

Or, the *least count* of a vernier is equal to the smallest division of the scale or limb divided by the number on the vernier. *

If $s = \frac{1}{2}$ degree, and $n = 30$, as ordinarily found on transit plates, the least count will be $\frac{1}{2} \div 30 = \frac{1}{60}$ of a degree = one minute.

If $s = \frac{1}{3}$ degree, and $n = 40$, as sometimes found on vertical arcs to solar attachments, the smallest reading $= \frac{1}{3} \div \frac{1}{40} = \frac{1}{120}$ of a degree $= \frac{1}{2}$ minute.

To space a vernier for a given least count, say $10''$ on a limb graduated to $10'$, we must have $n = \frac{s}{s-v} = 10 \div \frac{1}{6} = 60$ spaces, covering 59 spaces on the limb.

17. To read an instrument having a vernier consists in determining the number of units and fractional parts thereof, into which its scale or limb may be divided, from the zero point on the limb, where the graduation begins, to the zero point of the vernier.

It is accomplished as follows: Take the reading of the scale or limb, as shown by the last graduation preceding the zero of the vernier; then find a line on the vernier which coincides with a line on the scale or limb. The number of this line, as indicated by the graduation on the vernier, shows how many units of the *least count* are to be added to the first reading.

EXERCISES.

1. An arc is graduated into quarter-degrees, and a vernier of 30 parts covers 29 parts of the arc; find the least count.
2. Design a vernier, which, when applied to a limb graduated into $20'$, will give a least count of $20''$. †

* It is evidently immaterial whether LM be straight or curved.

† The foregoing description of the vernier is taken from the author's Treatise on Plane Surveying.

18. In running a long tangent, or prolonging a straight line with the transit, the instrument should be in good adjustment ; it should be properly centered, that is, set *precisely* over the center of the station from which the observation is to be made, especially if the point to be sighted — back sight — is near the observer. The error arising from an eccentric setting is inversely as the distance of the object sighted ; an eccentric setting of one inch producing an error of nearly three ($3'$) minutes of arc in sighting 100 feet, while the error arising from a sight of 900 feet is less than one-third ($\frac{1}{3}'$) of a minute. The instrument should be level, especially across the line of sight. The sight-pole should be held *plumb*, and *exactly* on the proper point. The observation should be made as near the bottom of the sight-pole as possible ; the line of sight as nearly horizontal, and the range in both directions as nearly equal, as practicable.

When a well-defined distant object can be sighted ahead, it is better to set the instrument by it than to trust to a back-sight.

When great accuracy is required, errors of adjustment may be lessened by reversing the instrument in altitude and azimuth, making two observations at each station, and taking the mean of their readings.

The transit notes are written from the bottom of the page upwards, analogous to the "column form" generally used in surveying land. The left-hand page of the transit note-book is usually prepared for this purpose, while the right-hand page is suitably ruled for recording some more details of the work as it may be necessary.

19. The chief of the field corps directs the operations of the party, provides accommodations and subsistence, and pays the necessary expenses. He indicates the direction of the line, establishes the deflection points, selects suitable sites for the crossing of streams, being careful always to run the line as nearly as his judgment dictates, and with the minimum grade in view, over ground likely to be chosen for location.

On preliminary work, especially in settled districts, the clearing should be kept at a minimum, that growing crops and forests be injured as little as possible.

The chief verifies and supplements the work of reconnoissance, he observes the quality of material to be moved, and the timber and rock, with a view of using them in the construction. He should be considerate of the rights of landholders and not do or allow anything to be done by any member of the corps which would tend to arouse active opposition to the project, but, on the contrary, by due regard endeavor to secure their aid.

20. The transitman keeps his instrument in adjustment, observes the direction of the line either by needle or plates, keeps the axemen in line when clearing, and the chainmen when measuring; he notes the directions and names of the principal highways and streams intersected, and, when practicable, property lines with the names of the owners. He records also the lengths of the lines run.

21. The head chainman when measuring advances with the chain and a sight pole, and being put in line, usually at a chain's length, by the transitman, directs the stakeman to drive a stake there. In a wooded district or brush land where much clearing is to be done, the head chainman should aid the transitman in giving *line* to the axemen, by going ahead and ranging it out.

22. The rear chainman should see that his end of the chain is held at the proper point, and that the chain is horizontal and taut when the head chainman is setting the next succeeding stake. If, for any reason, a portion of the line is run without stakes, and pins are used, he should keep the tally. He should see that the numbers placed upon the stakes by the stakeman indicating the stations are correct, and with this in view he should call out the numbers of the stations as he approaches them.

Should a change be made in the direction of the line, he should note mentally the *plus* if any, and be careful that the

next stake is set in its proper place, that the uniform distance between stations may be preserved. He should be provided with a book in which to record turning points, the intersection of streams, highways, and, when practicable, property lines.

23. The axemen do the necessary chopping and clearing the way, so that the transitman and leveler may have, if practicable, unobstructed sight, consistent however with the directions to the chief of party, and for economic reasons keeping the width of the cutting a minimum.

24. The stakeman marks or numbers the stakes and drives them vertically at points indicated by the head chainman, with the numbers so that they can be read by the rodman and topographer as they advance along the line. If stakes are not provided the party, it is the duty of the stakeman to keep himself supplied, using the proper means at hand. If, however, but little or no clearing is to be done, an axeman should be detailed to keep up the supply.

If the deflections of the lines are determined by the plates, a back flagman is required to give position of last transit point, but his services will not be needed if, as is sometimes the case, the bearings are taken directly by needle.

B. THE LEVEL PARTY.

25. The level party consists of a leveler and a rodman, and the instruments needed are a level, a rod, and a small axe.

THE Y LEVEL.

The principal adjustments are

1. The Line of Collimation.
2. The Level Bubble.
3. The Wyes.

26. To adjust the line of collimation, or to make it coincide with the optical axis of the telescope.

Set up the instrument firmly, remove the pins from the clips, clamp to spindle, and bring the intersection of the cross-

hairs upon a well-defined point a few hundred feet distant. Then carefully turn the telescope half-way round in the wyes ; the bubble-tube will then be above the telescope. Observe again the point, and see if the intersection of the cross-hairs is still on it. If it be not, then bring either or both cross-hairs, as may be required, half-way back, using the capstan-head screws perpendicular to the one which it is desired to move.

27. To adjust the level bubble, or to make the axis of the bubble-tube parallel to the longitudinal axis of the telescope.

a. Clamp the telescope over either pair of leveling screws, and bring the bubble to the center of its run. Turn the telescope in the wyes, so as to bring the bubble-tube a little to either side of the center of the bar. If the bubble runs towards either end, bring it back to the center by the capstan-head screws, which are set in either side of the tube-holder.

Again bring the bubble-tube to the center of the bar and the bubble to the center of its run ; turn the tube to either side, and repeat the correction if necessary until the bubble will keep its position when its tube is turned half an inch or more on either side of the bar.

The necessity for this operation arises from the fact that, when the telescope is reversed end for end in the wyes, in the other and principal adjustments of the bubble, we are not certain of placing the bubble-tube in the same vertical plane ; and, therefore, it would be almost impossible to effect the adjustment without a lateral correction.

b. Now bring the bubble to the centers of its run, and without jarring the instrument take the telescope out of the wyes and reverse it end for end. Should the bubble run to either end, bring it half-way back by lowering that end or raising the other, using the capstan-head screws at the end of the tube. Verify the adjustment.

28. To Adjust the Wyes, or to make the axis of the bubble-tube perpendicular to the vertical axis of the instrument.

Clamp the telescope in the wyes ; release from spindle, place the telescope over one pair of leveling screws and bring the bubble to the center of its run ; then turn the telescope hori-

zontally half-way round. If the bubble runs towards either end bring it half-way back by the adjusting screws at the end of the bar, and one-half by the leveling screws. Proceed in the same manner with the telescope for the other pair of leveling screws. Repeat the operation.

29. A surface like that of still water may be called a level surface. The curve formed by the intersection with such a surface of a vertical plane is a *line of true level*; a line tangent to the latter is a *line of apparent level*.

Leveling is the art of determining the differences of elevation of two or more points, or of determining how much one point is above or below a line of true level passing through the other point.

30. From the foregoing it is evident that, on account of the curvature of the earth, a horizontal line is not really throughout its length a level line; that of two points in the same level line each will have its own horizon. Hence in leveling the effect of the curvature of the earth upon the comparative elevations of different points must be taken into consideration. The effect of the curvature is to make objects appear lower than they really are. The air nearer the surface of the earth is denser than that farther removed from the surface. This difference in density, causing refraction of light, will affect the elevation of a point as observed through the telescope of a level, so that it also must be taken into consideration. Its effect is to make objects appear higher than they really are. The error caused by refraction is one-seventh as great as that caused by curvature.

Let us first find an expression for the correction due to the curvature of the earth. That is —

31. *To find the deviation from its tangent of a line of true level.*

Let O represent the center of the earth, PN a line of true level, and PN' its tangent, or a line of apparent level. The distance NN' corresponding to the length of sight PN is required.

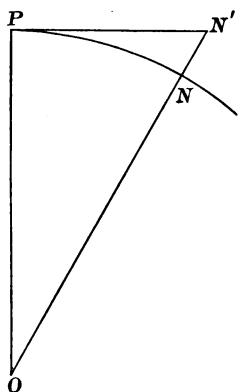


FIG. 6.

From Geometry,

$$\overline{PN}^2 = NN' (2 ON + NN');$$

$$\text{or, } NN' = \frac{\overline{PN}^2}{2 ON + NN'}.$$

For ordinary distances, the length of the arc may be regarded as that of the tangent, and NN' as inconsiderable in comparison with $2 ON$, the diameter of the earth. Therefore, calling the length of sight d , the correction c , and the radius of the earth r , we have

$$c = \frac{d^2}{2r}, \quad (3)$$

and the correction for refraction

$$= \frac{1}{7}c = \frac{1}{7} \times \frac{d^2}{2r} = \frac{d^2}{14r}; \quad (4)$$

then the correction due to curvature and refraction, which we will call C , is

$$c - \frac{1}{7}c = \frac{d^2}{2r} - \frac{d^2}{14r};$$

$$\text{or, } C = \frac{3d^2}{7r}. \quad (4a)$$

This correction must be added to the height of the object as found by the level.

In practice, the necessity for using the above formula is avoided whenever it is possible to set the level at equal distances from the points whose difference of height is required.

EXERCISES.

1. Assuming the diameter of the earth 7,926 miles, show that for a mile sight c = about 8 inches. Find the value of C for the same distance.

2. What is the correction due to curvature for half a mile? Two miles?

3. What is the length of sight when C equals one-tenth of a foot?

4. Show that, practically, the correction for curvature in feet is equal to two-thirds the square of the distance in miles.

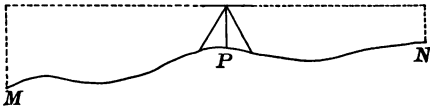


FIG. 7.

32. If two points M, N , whose difference of elevation is required, can be observed upon from some point P about equidistant* from them, not necessarily in their line, set up the level at P , and note the reading of a rod held vertically over each point. The difference of the two readings will indicate the difference of level required.

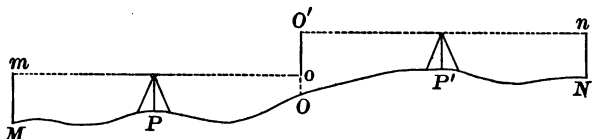


FIG. 8.

33. If the above method is impracticable, set up the instrument at some point P — either in or out of the line, no matter which — from which a rod may be observed on the first station M , and also on another point O , in the direction of N , about equidistant with M from the instrument. Remove the level to a new position P' , whence observe again the rod on O , also the rod reading at N .

The difference between the readings of the rod at M and O shows how much higher the latter is than the former, and in like manner the difference of the readings at O and N gives

* Placing the instrument in this position lessens the effects of inaccurate adjustment and renders unnecessary the corrections indicated in Article 31.

the difference in elevation of these points, and so on, no matter what the number of stations. The difference in height of M and N

$$\begin{aligned} &= Mm - Oo + Oo' - Nn; \\ \text{or,} \quad &Mm + Oo' - Oo - Nn \\ &= Mm + Oo' - (Oo + Nn). \end{aligned}$$

Calling Mm and Oo' back-sights, and the other two, fore-sights, we perceive that the difference of level of two points is shown by subtracting the sum of the fore-sights from the sum of the back-sights.

34. Again, in leveling, we measure, by means of the rod, how much lower than the line of sight (height of instrument) certain points are. Thus we may determine the relative elevations of the points. Suppose, for example, it be required to determine the difference in elevation of any two points. For reasons already given, set the level equally distant from the points. If this cannot be done, and both observations have to be taken from one of the stations, especially if the distance between them is considerable, correction as previously described must be made. But in this case suppose it is possible; and suppose that when held on one point, the rod reads 7.255; that is, this point may be considered 7.255 below the line of sight, and 4.755 when held on the other; then the first may be considered $7.255 - 4.755$, or 2.500 farther than the second below the line of sight, or lower than the second.

35. Suppose it be required to determine the difference in elevation between two points, of which one is so much higher than the other that the rod is too short to give a reading on both points for one position of the instrument. In such a case one or more auxiliary points, called turning points (T. P.), must be used, and their relative elevations determined. Suppose the reading on the first point is 0.824, and on a turning point is 10.432; the latter is then 9.608 below the former. Now the instrument must be moved and set up so as to obtain a reading on the turning-point, and (we will suppose) on the other of the given points.

Suppose that on the former it is 1.302, and on the latter 8.634; the latter is then 7.332 below the turning-point, or $9.608 + 7.332$, or 16.940 below the first of the two given points.

The first sight taken after setting up the level is called a back-sight, or plus sight; those taken after this, and before the instrument is moved, are called fore-sights, or minus sights. As the difference of the readings of the rod on two points gives their difference of elevation, so the difference of the sum of the plus sights, and the sum of the minus sights on T. P.'s and the last point will give the difference in elevation of the extreme points. In the above example.

0.824	10.432
<u>1.302</u>	<u>8.634</u>
2.126	19.066

$19.066 - 2.126 = 16.940$, as before.

This is used as a check on level-notes.

In extended leveling, permanent elevations, fixed during the progress of the work for future reference, are called bench marks, or benches (B. M.).

36. In leveling, it is customary to refer all elevations to an assumed level plane, called the plane of reference, the datum plane, or simply the datum. Points are then said to be so much above or below the datum. As this plane may be assumed at pleasure, it is generally so taken as to be lower than any point whose elevation is to be determined.

If the beginning of a survey is in the vicinity of tide-water, this plane is assumed at the height of mean low water, which elevation may be called zero. Then a point which has the elevation 125.37 will be 125.37 above low water.

If two points have the elevations 125.375 and 105.213, respectively, the former is $125.375 - 105.213$, or 20.162 higher than the latter.

The datum having once been determined, its elevation, or that of a point a known distance above it, should be permanently fixed for future reference and comparison.

37. There are various forms employed for recording level notes. The following is simple and convenient : —

	STA.	+S.	H.I.	—S.	ELEV.	REMARKS.
	B.M.	4.725			100.000	On S. end, lower step, University, Main Bldg.
	0		104.725	2.44	102.285	
	1			1.25	103.475	
T.P.	+60	8.417		.50	104.225	Pt. on sidewalk, S. of Main Bldg.
	2		112.642	7.80	104.842	
	3			6.50	106.142	
	4			4.28	108.362	
T.P.	5	3.365		1.36	111.282	
	6		114.647	1.25	113.397	
	7			5.45	109.197	

The bench mark is assumed to be 100 feet above the datum. The first plus sight is 4.725, which added to 100 gives 104.725, the height of the instrument (H. I.) above the datum. The first minus sight is taken on station 0, and is 2.44, which subtracted from 104.725 gives 102.285, the height of this station above the datum. Similarly, the height of station 1 and plus 60 are obtained, the latter being a turning point. The instrument is then carried forward, set up again in a convenient place to sight the T. P. and other points in the line, and thus the work proceeds.

At one setting of the instrument the elevations of points, besides the turning points, which are not too high or too low to be reached, may be ascertained. It is evident that if any error be made at a T. P., all the following elevations will thereby be affected ; but if made at one of the other points, only the elevation of that point will be affected. Hence the importance of careful observations at the T. P.'s.

38. Wind and sunshine affect the accuracy of leveling as of work with the transit. For very good work it is desirable to have a calm day on which the sun is obscured by clouds. In addition to a proper manipulation of the instrument, the sights should not exceed 300 feet, the rod should be held ver-

tical, and the rodman should select for turning-points good and firm points on stones, pegs, etc., on which the rod may be freely turned or spun around. Test the arithmetical work in the foregoing table as indicated in Art. 35.

39. The leveler keeps his instrument in adjustment, sights the rod when held on stations, turning points, or benches of the rodman, and records his readings in a book provided for the purpose. He ordinarily takes a bench reading every 1500 or 2000 feet, and oftener in a hilly district. If the benches are judiciously chosen they may frequently serve as turning points, and a saving of time be thereby effected.

The rod should be read to tenths of a foot on *intermediates* and to thousandths of a foot on benches and turning points.

The leveler should observe the surface, and when practicable the high water mark, of creeks and rivers. He should use a Locke level to take the heights when crossing deep gulches or narrow ravines, and thus save the time required to *peg* in the usual way. The profile should be made up daily.

40. The rodman holds his rod vertically for observation by the leveler at every stake, the number of which he calls out to him, and wherever there is an observation to be taken on a *plus*, for instance on bank or in bed of stream, he should make known to the leveler its amount. He should be quick to perceive a *singular point*, and prompt to decide whether a *plus* observation is required on it. He should note the position of benches and turning points, so as to find them readily, should it be desired to re-level the line. He should assist the leveler when required to make up the profile.

C. THE TOPOGRAPHIC PARTY. ,

41. It is the duty of the Topographic party to indicate the position of the prominent features of a belt of country extending both ways from the center line of the survey, including woodland, streams, roads, buildings, etc., and to obtain the necessary data to make a contour map of it.

The party usually consists of a topographer and two assistants. They need a tape, rod, and an instrument for

measuring slopes, which may be a clinometer, cross-section pole (slope board), or a Locke level. A small prismatic compass is sometimes carried to observe the direction of objects. Buildings, roads, streams and other objects are usually located by offsets from the center line.

42. The data for the contour map is obtained by observing from every station the slope of the ground at right angles to the proposed line, and on both sides of it.* The distance between points of successive contours being taken by the assistants, and the total distance out from the center varying from about 50 feet to several hundred feet, as may be needed by the chief engineer in determining the final location.

It will be perceived that the topographic work is connected with that of the level-party, and since the elevations of the stations are given by the latter, the data for a contour map can be easily obtained.

For instance, if a station in the center line, as shown by the level notes, has an elevation of 852.4 feet, and five-foot contours are being taken, it is evident that the 850-foot contour passes 2.4 below this point. Suppose the Locke level is used; then if the observer, whose eye we shall assume is five feet high, stands at the station, and his assistant holds a rod at a point where the line of sight intersects it at 7.4, the foot of the rod will be on the 850-foot contour. Measure from the station to this point, and from the point observe a reading of ten feet on the rod, which will show the 845-foot contour. Measure to this point, and continue the observations until the limit of measurement in this direction is attained. Proceed in a similar manner to take the slope of the upper side, and so pass along the entire line. Otherwise the observer places himself where the rod reading on the station is 2.6 feet, then his line of sight will indicate the 855-foot contour; he evidently stands on the 850-foot contour, and without changing place he discovers the 845-foot contour where the rod reads 10 feet.

* Sometimes on preliminary work, and especially where the ground is gently undulating, the contours are taken from stations, 200 or 300 feet apart.

Measure from the station and locate the points as above. In a similar manner the Topographer will stand on the 840-foot contour when sighting the bottom of rod held on the 845-foot contour, whence a rod placed so as to give a reading of 10 feet will indicate the 835-foot contour. In a corresponding manner the contours on the upper side of the line may be shown. If the height of the observer's eye is not 5 feet proceed in general as though using the wye level. The record may be kept in fractional form, the numerator indicating the contour, and the denominator the distance of the observed point in it from the center line.

In a similar manner a simple cross-section at any station can be obtained; the height of the eye giving the difference in elevations at the successive points of observation, the distances between these being measured by the tape. If a cross-section pole (called also a slope board) and leveling rod are used, the pole is held level and the rod indicates the difference in height of its ends, while the length of the pole, usually 10 or 12 feet, gives the distance between the successive readings. Cross-sections may be taken very rapidly by either of these methods.

In the office the contour map is made by connecting the points of equal height, and writing the elevation on the several lines.

Let Fig. 9 represent a portion of a contour map drawn to a scale of 400 feet to the inch. We will suppose the line nearest the top of page to be 100 feet above datum or the 100-foot contour, and the farthest one the 130-foot contour. The difference between the successive contours being 5 feet. The dotted line represents the contour of the grade rising one foot per station, or a one per cent. grade, from *L* to *N*. If this line be adopted for the location, there would be neither center-cut nor center-fill. If the straight line *LN* is adopted, the plan shows that there would be a center-cut at *b* of about 11 feet, one at *g* of 3 feet; and a center-fill at *e* of 14 feet, but at *d* and *f* there would be neither cut nor fill, hence these are *grade points*. The cuts and fills at the center of the line being shown by the number of spaces and fractions thereof between the adopted line and the grade-contour, and hence a tolerably close approxi-

mation may be made as to quantities. Table XIV will be found useful in this connection. While, therefore, the line *LN* has the advantage of being shorter than the dotted line, it has the disadvantage of a heavier grade, besides the cuts and fills named.

Various conditions and circumstances, it will be readily perceived, present themselves to the engineer in deciding the precise location of a center line of any great extent.

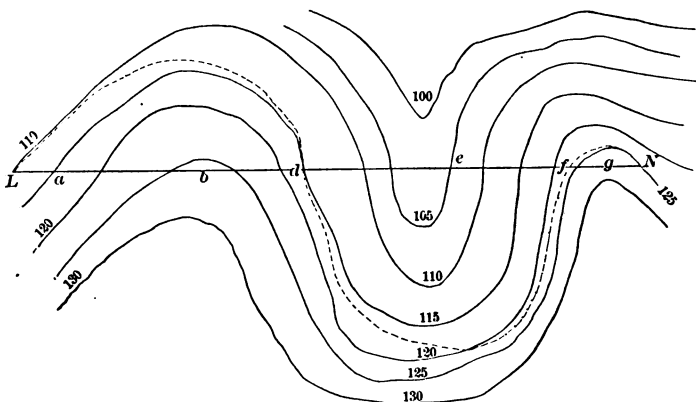


FIG. 9.

43. The small plan above simply serves as an illustration, but to more fully comprehend the difficulties surrounding this important matter of location, one should imagine that the engineer has before him a contour map of a belt of country several miles in extent, that he is endeavoring to decide upon the best location of a line in that belt; and consider what are the questions which present themselves to him for solution, and what are his limitations. He desires to make the line as near straight as practicable between certain points; the grade the best possible, in no case to exceed a certain amount; the cost of construction a minimum. It is evident also that the expense of operating and maintaining the road is involved in this decision. The cost of the earth work will in general be

lessened by equalizing as far as practicable the material in cuts and fills. This, however, is not always possible, because of the necessity of crossing other public highways or streams at fixed grade. To lessen solid rock cutting he may consider the question of change of grade or direction from what otherwise he would deem the proper location. This change, if made, may necessitate *borrowing* material elsewhere. To secure proper drainage in a flat and wet section, the question of *waste* of material or its transportation a distance to fill must be settled.

These, and numerous other questions of a similar character, present themselves in the decision of this matter; and to answer them properly, and thus make the best location possible under all the conditions and circumstances, an opportunity is offered the engineer for the display of his best judgment.

In passing upon the question of equalizing cuts and fills, it must be remembered that rock measured in excavation will, when broken and thrown in embankment, show an increase in volume of about two-thirds; that is to say, 3 cubic yards of solid rock in cut will make about 5 cubic yards in fill. The shrinkage of earth soils, which is about one-tenth, is generally ignored in this connection, though it too should be considered when setting out the work for the contractor. See Art. 113.

The student may sketch a contour map showing a descending grade of $1\frac{1}{2}$ feet per station, and determine the depth of cuts and fills.

44. The engineer is thus enabled to make a paper location, establish grades, and estimate approximately the quantity of material to be removed. The center line must then be staked out, curves run in to connect the tangents, stakes being set carefully and firmly every 100 feet, at the beginning and ending of every curve, on the banks of creeks and edges of ravines intersecting the line, and at all other points where, in the judgment of the engineer, the work of construction will be expedited thereby; the more important points in the line being also referred to other points at known distances and

directions. These reference points (R.P.'s) should be located sufficiently far from the field of operations that they will not likely be disturbed during the progress of the work. The levels must be carefully taken on all points in the line set by transit, and plusses taken and the rod read on other points in the line where there is a noticeable change in its direction vertically, that a correct profile may be made, and the work of cross-sectioning be facilitated.

The leveler should select his benches so far from the line that they will be undisturbed during the construction, and when practicable make them nearly at grade for convenient future reference. The rod should be read to thousandths on benches and turning points, but only to tenths on intermediates.

The width of strip, or right of way, required for railroad purposes is a variable quantity depending upon the width of the roadbed and the depth of cuts and fills. A general rule adopted by some roads is to have 30 feet besides the slopes for single track and 60 feet and slopes for double tracks. That is to say, where there is a 16-foot cut with slopes $1\frac{1}{2}:1$ the required width would be

$$30 + 2 (1\frac{1}{2} \times 16) = 78 \text{ feet.}$$

At grade 30 feet would be the width required for single track, and 60 feet for double track. It will readily be perceived that the right of way cannot always be figured from the *center* cut or fill, since there may be a cut or fill at the side where the center is at grade.

CHAPTER III.

SIMPLE CURVES.

A. DEFINITIONS AND FUNDAMENTAL FORMULAS.

45. The **center line** of a railroad is composed of straight lines and curves. The straight lines are called **tangents**; the **curves** are usually arcs of circles, and are simple, compound or reversed.*

a. A **simple curve** is the arc of a circle.

b. A **compound curve** is composed of two simple curves, or branches, of different radii, both lying on the same side of a common tangent drawn at their point of union, as BE , Fig. 10.

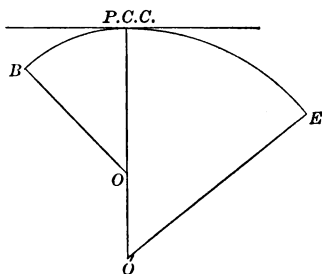


FIG. 10.

c. A **reversed curve** is composed of two simple curves, or branches, of the same or different radii, lying on opposite sides of a common tangent drawn at their point of union, as BE , Fig. 11.

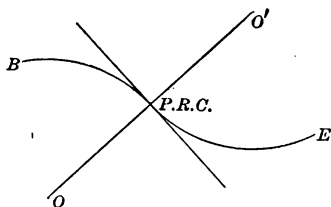


FIG. 11.

d. The **point of curve**, or the P.C., is the point at which the tangent AB ends, and the curve BNE begins, as B , Fig. 12.

e. The **point of tangent**, or the P.T., is the point at which the curve BNE ends, and the tangent EF begins, as E , Fig. 12.

* As a rule reversed curves are not admissible on main line, but they are properly used in connection with cross-overs, sidings, and in yards.

f. **The point of intersection**, or the P.I., is the point of intersection of the tangents drawn through the P.C. and the P.T., as I.

g. The radius BO , or EO , is denoted by R .

h. **The point of compound curve**, or the P.C.C., is the point of common tangent of its two branches. See Fig. 10.

i. **The point of reversed curve**, or the P.R.C., is the point of common tangent of its two branches. See Fig. 11.

j. **The angle of intersection**, or α , indicates the amount of divergence of the tangents BI and IE . Fig. 12.

k. **The tangent distance**, or T , is the distance BI or EI from the P.C. or P.T. to the point of intersection.

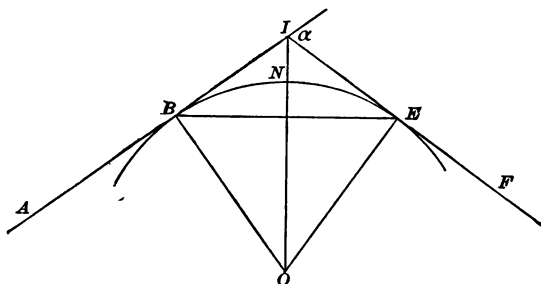


FIG. 12.

46. Chords of one hundred feet are generally used, not the actual arc, in running a curve, and the amount of curvature is designated by the degree, though sometimes by the radius of the curve.

47. The degree of the curve D , as usually defined is the angle AOB , Fig. 13, at the center, subtended by a chord as AB of 100 feet length. If it were practicable to measure 100 feet along the arc AB instead of the chord, and substitute hence, in the definition for degree of curve, the word *arc* for *chord*, a precise and convenient ratio would be always available between the radius and degree of curve; for we should then have

For a 1° curve, $2\pi R_1 = 100 \times 360$; $\therefore R_1 = \frac{36000}{2\pi} = 5729.58$.

“ 2° “ $2\pi R_2 = 100 \times 180$; $\therefore R_2 = \frac{18000}{2\pi} = 2864.79$.

“ 3° “ $2\pi R_3 = 100 \times 120$; $\therefore R_3 = \frac{12000}{2\pi} = 1909.86$.

“ n° “ $2\pi R_n = 100 \times \frac{360}{n}$; $\therefore R_n = \frac{100}{2\pi} \times \frac{360}{n}$.

The inverse ratio existing between the degree of curve and the radius being apparent. But since the arc measurement is impracticable the chord being substituted therefor, and since the difference in length between an arc and its chord increases with the degree of curve the radii obtained as functions of the chords, will not agree exactly with those computed as above. The question therefore arises to what extent is it consistent with good practice to assume the equality of arc and chord. In this connection consider the following problem.

48. To find the radius R , in terms of the degree of curve

D . Draw OM perpendicular to the 100-foot chord AB . Denote OA by R , and the angle AOB by D . Then in the right triangle AMO we have

$$R \sin \frac{1}{2} D = AM, \text{ whence } R = \frac{50}{\sin \frac{1}{2} D} = 50 \operatorname{cosec} \frac{1}{2} D, \quad (5)$$

and conversely the degree of curve in terms of the radius.

$$\sin \frac{1}{2} D = \frac{50}{R}. \quad (6)$$

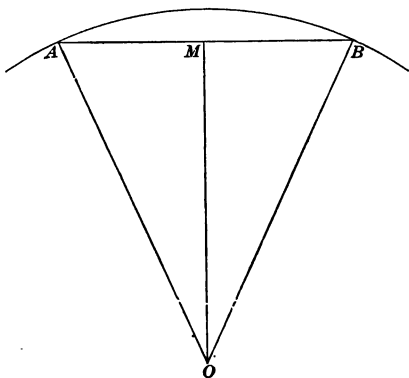


FIG. 13.

Applying this formula to compute R for a one degree curve according to the definition of the degree of curve we obtain,

1° curve, $R = 5729.65$	8° curve, $R = 717.78$
2° “ $R = 2864.93$	10° “ $R = 573.69$
3° “ $R = 1910.08$	14° “ $R = 410.28$
5° “ $R = 1146.28$	15° “ $R = 383.06$
7° “ $R = 819.02$	20° “ $R = 287.94$

Comparing the corresponding values of R in the two sets given above we perceive the difference.

For a 1° curve	$= 5729.65 - 5729.58 = 0.07$
“ 2° “	$2864.93 - 2864.79 = 0.14$
“ 3° “	$1910.08 - 1909.86 = 0.22$
“ 5° “	$1146.28 - 1145.92 = 0.36$
“ 7° “	$819.02 - 818.51 = 0.51$
“ 8° “	$716.78 - 716.20 = 0.58$
“ 10° “	$573.69 - 572.96 = 0.73$
“ 14° “	$410.28 - 409.26 = 1.02$
“ 15° “	$383.06 - 381.97 = 1.09$
“ 20° “	$287.94 - 286.48 = 1.46$

The difference is about a half a foot in a 7° curve and about a foot in a 14° curve ; so that for ordinary work it is permissible to stake out curves from 1° to 7° inclusive with chords of 100 feet, using formula (5) to obtain R . From 8° to 14° inclusive use chords of 50 feet, whence

$$R = \frac{25}{\sin \frac{1}{2} D} = 25 \operatorname{cosec} \frac{1}{2} D. \quad (6a)$$

From 15° to 28° inclusive use chords of 25 feet, whence

$$R = \frac{12.5}{\sin \frac{1}{2} D} = 12.5 \operatorname{cosec} \frac{1}{2} D. \quad (6b)$$

For a greater degree, stakes should be set in the curve every 10 feet, and the value of the corresponding radius

$$R = \frac{5}{\sin \frac{1}{2} D} = 5 \operatorname{cosec} \frac{1}{2} D. \quad (6c)$$

The practical effect of the application of the above formulas is that when the degree of curve is assumed, the radius can be determined at once by simple division, and *vice versa*, if the

radius is known, the degree of curve D , can be found. Thus, suppose D is 2° .

$$\text{Then} \quad R = \frac{5729.65}{2} = 2864.83 \text{ feet.}$$

Or, as is frequently done, taking the radius of a 1° curve as 5730 feet,

$$R = \frac{5730}{2} = 2865 \text{ feet.}$$

The assumption of 5730 feet as the length of the radius of a 1° curve lessens the slight error committed in assuming the equality of arc and chord for the same central angle and radius when the angle is 2° and over; and the difference is inconsiderable for angles even less than 2° . That is to say, the radius of a $2^\circ 30'$ curve is more nearly $\frac{5730}{2\frac{1}{2}} = 2292$, than it is $\frac{5729.65}{2\frac{1}{2}} = 2291.86$, and the radius of a 3° curve more nearly one-third of 5730 = 1910 than it is one-third of 5729.65 = 1909.88.

The student may verify these results, and explain why the above assumption lessens the error.

EXAMPLES.

1. Find the length of R when $D = 6^\circ 38'$.
2. Find D if $R = 5000$ feet.
3. Find R if $D = 30$ minutes.
4. Find R if $D = 30$ degrees.
5. Find the degree of curve when R is 250 feet, and state how far apart the stakes should be set.

49. Stations are usually placed 100 feet apart and numbered, beginning at zero (0). Short chords, called sub-chords, may, therefore, occur at the ends of a curve.

a. **The deflection angle** is the angle IBG or GBH , Fig. 14, at any point in the curve subtended by a chord of 100 feet, and $= \frac{1}{2} D$.

b. **The middle ordinate** M is the perpendicular MN from the middle of a chord to the arc, or it is that part of the radius

intercepted between the middle of the chord and its arc, corresponding to the versed sine of half the arc.

c. **The long chord C** , as usually defined, is the line BE joining the beginning and ending points of the curve, though the term *long chord* is often used in practice to designate any chord of the curve greater than 100 feet in length, as BH .

d. **The external distance E** is the line NI joining the middle of the curve with the intersection point I , and is, therefore, the prolongation of the radius from N to I .

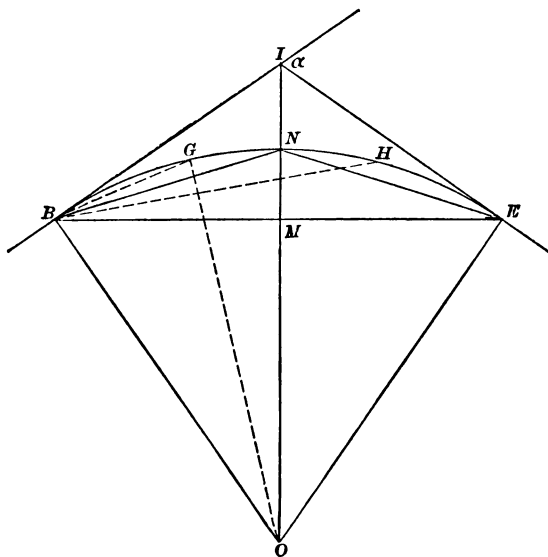


FIG. 14.

50. **The length of a curve L** is given by the number of applications and fractions thereof, if any, of the chord used in laying out the curve, or the number of stations and fractions thereof, if any, which compose the curve.

$$\text{In general} \quad \frac{\alpha}{D} = \frac{L}{100}.$$

$$\text{The actual length of arc} = \frac{2\pi R\alpha}{360}.$$

The distance from station 44 to station 55 = 11 stations or 1100 feet. From station 44 to a point 60 feet beyond station 55 = 1160 feet, and such point would be marked and called 55 + 60, or may be said to be 11.6 stations from 44.

51. From the properties of the circle it will readily appear —

(a) That the radii OB and OE are respectively perpendicular to the tangents IB and IE .

(b) That the tangents IB and IE are equal.

(c) That the angle of intersection α is equal to the angle BOE at the center, called also the central angle.

(d) That the angle $IBE = IEB = \frac{1}{2} BOE = \frac{1}{2} \alpha$.

(e) That the angle $IBN = NEI = NBE = NEB = \frac{1}{4} \alpha$.

(f) That the angle $IBG = \frac{1}{2} BOG = \frac{1}{2} D$ when $BG = 100$ feet.

When the length of a circular arc as BGE = the length of the radius BO or OE it is called the unit arc, and the angle $BOE = 57.3^\circ$; hence if one degree is subtended by a chord of 100 feet

$$R = 57.3 \times 100 = 5730 \text{ feet.}$$

Since the chords and sines of small arcs or angles practically coincide, the value of either for 1° being .01745, the divergence per station, or 100 feet, will be nearly 1.75 feet, for $D = 1^\circ$. For a 2° curve, 3.5 feet; and so on in arithmetical ratio, approximately correct for 6° or 7° , and may be used for roughly setting out a curve, or as a help and check on the instrumental operations in locating points in a curve.

EXAMPLES.

1. Given the angle of intersection $\alpha = 22^\circ 40'$ and $D = 3^\circ 20'$, to find the length of the curve :

$$22^\circ 40' = 22\frac{2}{3}^\circ = \frac{68}{3}^\circ$$

$$3^\circ 20' = 3\frac{1}{3}^\circ = \frac{10}{3}^\circ$$

$$\frac{68}{3} \div \frac{10}{3} = \frac{68}{3} \times \frac{3}{10} = 6.8 \text{ stations} = 680 \text{ feet. } \textit{Ans.}$$

2. Given $\alpha = 31^\circ 51'$ and $D = 2^\circ 46'$, to find the length of the curve :

$$31^\circ 51' = 1911 \text{ minutes}$$

$$2^\circ 46' = 166 \quad "$$

$$\frac{1911}{166} = 11.51 \text{ stations} = 1151 \text{ feet. } \textit{Ans.}$$

REMARK 1.—If, as in Example 1, the minutes can be readily turned into convenient fractional parts of a degree, it is best so to reduce them, and then divide out. If, however, as in Example 2, the fractional parts would not be so convenient, it is best to reduce both to minutes before dividing.

REMARK 2.—In ordinary preliminary work, it will be sufficient to measure lengths to the nearest foot, and to take the needle-bearings of the tangents. This practically requires the reading of the tape to be made to half a foot: that is, a line which, if read to tenths, would equal 348.7 feet, would be recorded 349 feet; if 348.4, would be recorded 348. On location, however, the angles should be read off the plates by the vernier to the minute, and the measurements should be made ordinarily to within two or three tenths. If there be conditions requiring greater accuracy, as in determining the area of valuable property in connection with the right of way, etc., then of course the measurements should be correspondingly close, say to a tenth of a foot. No strict rule can be laid down; the engineer must use his judgment in this matter as in many others, and make the degree of precision consistent with the interests involved.

REMARK 3.—*For all ordinary calculations in the field use the natural functions, sines, tangents, secants, etc., true to four places of decimals, tables of which are found in this book. Waste no time with logarithms, for even without wind, rain, or bright sun to contend with, the seeking of the logarithmic quantities in the different tables—in all field books the figures in the tables are necessarily small—and then after addition finding the corresponding number, will consume so much time that the Napierian follower will generally be found far behind one who adopts the more primitive mode of computation. Table II, explained on page 42, containing tangents and external distances of a 1° curve, will also be found useful, easily applied, and sufficiently accurate for common field practice, and by consulting it for these functions the transitman will often save himself much calculation.*

3. Given the length of a curve 510 feet, and $D = 2^\circ 40'$ to find α . *Ans.* $13^\circ 36'$.

4. A 3° curve begins at station $22 + 36$, and ends at $29 + 84$, find the length of the curve, the radius, and central angle.

5. Given the angle of intersection $53^\circ 57'$, and the degree $5^\circ 43'$ to find the length of the curve.

6. How much longer is the arc than its 100-foot chord, the radius being 500 feet? If the radius is 1000 feet? 2000 feet?

52. Given the angle of intersection α , and the radius R , or degree D , to find the tangent distance.

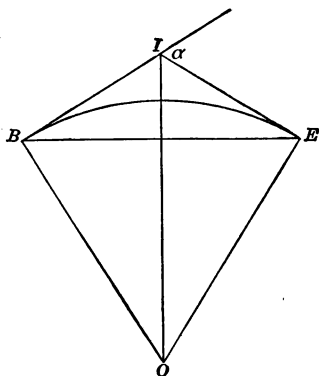


FIG. 15.

In the right triangle BOI the angle $BOI = \frac{1}{2} \alpha$.

$$\text{Therefore} \quad T = R \tan \frac{1}{2} \alpha, \quad (7)$$

and substituting for R its value from (5)

$$T = \frac{50 \tan \frac{1}{2} \alpha}{\sin \frac{1}{2} D} = 50 \tan \frac{1}{2} \alpha \operatorname{cosec} \frac{1}{2} D. \quad (8)$$

This formula is useful when the radius OB or degree of curve is assumed, the tangent distance IB must then be calculated. If, on the other hand, T be assumed, then we may find R , and hence D , from the problem —

53. Given the tangent distance T and the central angle α , to find the radius.

From (7)

$$R = T \cot \frac{1}{2} \alpha. \quad (9)$$

EXAMPLES.

1. Given the tangent distance 450 feet, and the angle of intersection $23^\circ 42'$ to find the radius.

2. Given the angle of intersection $17^\circ 56'$, and the degree of curve $2^\circ 40'$, to find the tangent distance.

54. Given the radius R and central angle α , to find the long chord C .

In the right triangle BOm Fig. 16

$$Bm = BO \sin BOm$$

$$\text{or,} \quad \frac{C}{2} = R \sin \frac{1}{2} \alpha.$$

$$\text{Hence} \quad C = 2 R \sin \frac{1}{2} \alpha. \quad (10)$$

The student may show that,

$$C = 2 T \cos \frac{1}{2} \alpha, \quad (11)$$

$$\text{and that} \quad C = 2 M \cot \frac{1}{2} \alpha. \quad (12)$$

Example — Given a $2^\circ 50'$ curve, having a central angle of $28^\circ 30'$, to find the long chord.

55. Given the radius R and central angle α , to find the middle ordinate M .

$$mN = BO \text{ versine } BOm;$$

$$\text{or,} \quad M = R \text{ versine } \frac{1}{2} \alpha. \quad (13)$$

Example — Given a $3^\circ 40'$ curve having a central angle of $32^\circ 50'$ to find the middle ordinate.

If α and the external distance E are given, to find M , substitute in (13) the value of R from the proportion,

$$\begin{aligned} \text{cosine : } R &= \text{versine : exsec, or } E, \text{ and we obtain,} \\ M &= E \cos \frac{1}{2} \alpha. \end{aligned} \quad (14)$$

The student may verify the last equation by another method.

56. Given the radius R and chord C to find the middle ordinate M .

$$mN = ON - Om.$$

$$\text{But} \quad Om = \sqrt{OE^2 - mE^2},$$

and substituting values, there results,

$$M = R - \sqrt{R^2 - \frac{C^2}{4}}. \quad (15)$$

The last term of this series will not affect the result .03 of a foot for M of a chord 100 feet and radius 300 feet, and may be, therefore, safely rejected; we have then,

$$M = \frac{C^2}{8R}; \quad (17)$$

And hence for any other middle ordinate M_1 and chord C_1 in the same curve,

$$M_1 = \frac{C_1^2}{8R}. \quad (17a)$$

or, $M : M_1 = C^2 : C_1^2,$

$$\therefore M_1 = M \cdot \frac{C_1^2}{C^2}.$$

If $C_1 = \frac{1}{2} C,$ $M_1 = \frac{M}{4}. \quad (18)$

Assuming $BN = \frac{1}{2} BE$ (which may often be done with sufficient accuracy), its middle ordinate $m'n' = \frac{1}{4} M$, and the middle ordinate of $Bn' = \frac{1}{4} m'n'$, and so on, numerous points in a curve may be established.

Practically these points may be located by measuring off the computed distance, as $m'n'$, from the middle point of a tape stretched between the extremities of an arc, as BN .

EXAMPLES.

1. Find the middle ordinate, and the length of one 25 feet therefrom, of a 100-foot chord, the radius being 1000 feet.

2. Given the radius of a curve 500' and chord 100' to locate in the arc points whose projections on the chord shall be $12\frac{1}{2}$ feet apart. Compare results by different methods.

58. Given the radius R , and central angle α , to find the external distance E . As Bm is the sine and mN the versed sine to radius R of the arc BON , Fig. 17, so is NI the external secant of the same arc and radius.

$$\therefore E = R \cdot \text{exsec } \frac{1}{2} \alpha. \quad (19)$$

Hence **given the external distance E and central angle α to find the radius R ,**

$$R = \frac{E}{\text{exsec } \frac{1}{2} \alpha}. \quad (20)$$

on the bisector from I to the center of the track, and thereby get E . The values of E and α , being thus discovered and substituted in the equations named, make known R and T .

EXAMPLES.

1. Given the central angle $28^\circ 48'$, and degree of curve $4^\circ 40'$, to find the external distance.

2. Given the angle of intersection $44^\circ 56'$, and the tangent distance 560 feet, to find how far from I to the nearest point on the curve.

3. The angle of intersection is $32^\circ 20'$, and the curve passes within 60 feet of I . Find the distance from the P.I. to the P.C.

4. The angle of intersection is $26^\circ 40'$, and the nearest point of the curve is to be 56 feet from I . Find the radius and degree of curve.

Tangents and external distances for a one-degree curve for every ten minutes of central angle are arranged in table II. In this table, therefore, one may find the length of tangent or external distance at once corresponding to a radius of 5730 feet, and a central angle varying by ten minutes of arc, and by interpolation he may obtain these lengths for any minute whatever.

For the required length of a corresponding tangent, or external distance of any other radius or degree of curve, take the proportional part thus: To find the length of a tangent corresponding to a 3° curve and central angle 24° , look in table II under 24° , and take out of the column of tangents, opposite 24° , the number 1218. This is the length of the tangent of a 1° curve having a central angle of 24° .

Now the tangent of a 3° curve, and the same central angle, is only one-third as long; hence, $1218 \div 3 = 406 =$ length of chord required.

The student may verify this result by either formula (7) or (8).

EXAMPLES.

[To be solved by aid of Table II.]

1. Given the intersection angle $\alpha = 48^\circ 26'$, and $D = 5^\circ$, to find the tangent distance.

2. Given $\alpha = 28^\circ 20'$, and the length of the tangent = 361.6 feet, to find the radius. *Ans.* 1432.5 feet.

3. Given the angle $\alpha = 36^\circ 40'$, to find the external distance and tangent of a $3^\circ 40'$ curve.

4. Given the tangent distance $T = 559$ feet, and $D = 4^\circ$, to find α . *Ans.* $42^\circ 38'$.

5. Given the external distance 126.1 feet, and $D = 2^\circ 40'$, to find α .

SOLUTION.—Find the product of 126.1 by $2\frac{3}{4} = 336.3$ in the table in the *E* column, and note the degrees and minutes corresponding thereto = $38^\circ 20'$. *Ans.*

The following formulas derived on preceding pages are grouped here for convenience of reference.

R = Radius.

C = Long chord.

L = Length of curve.

M = Middle ordinate.

T = Tangent distance.

E = External distance.

c = Any chord.

$$R = \frac{50}{\sin \frac{1}{2} D}$$

$$T = \frac{C}{2} \sec \frac{1}{2} \alpha$$

$$R = 50 \operatorname{cosec} \frac{1}{2} D$$

$$T = 50 \tan \frac{1}{2} \alpha \operatorname{cosec} \frac{1}{2} D.$$

$$R = T \cot \frac{1}{2} \alpha$$

$$T = R \tan \frac{1}{2} \alpha$$

$$R = \frac{E}{\operatorname{exsec} \frac{1}{2} \alpha}$$

$$T = E \cot \frac{1}{2} \alpha$$

$$R = \frac{C}{2 \sin \frac{1}{2} \alpha}$$

$$T = \frac{50 \tan \frac{1}{2} \alpha}{\sin \frac{1}{2} D}$$

$$R = \frac{M}{\operatorname{versine} \frac{1}{2} \alpha}$$

$$C = 2 R \sin \frac{1}{2} \alpha$$

$$C = 2 T \cos \frac{1}{2} \alpha$$

$$L = 100 \frac{\alpha}{D}$$

$$C = 2 m \cot \frac{1}{2} \alpha$$

measure in the direction of the line of sight 100 feet and there set C . Deflect again $CBF = \frac{1}{2}D$, i.e., make the reading of the plates now $=D$, and measure from C onward 100 feet, to a point F in the line of sight, thus locating F . Deflect again the angle $FBG = \frac{1}{2}D$, making the reading of the instrument $\frac{3}{2}D$, and measure 100 feet from F to G , and so on as far as may be necessary. If the curve is to be extended farther than it can be seen from the point B , the direction of the tangent at the point on the curve on which it is desired to place the instrument must be ascertained; hence the problem.

61. To find the direction of a tangent at a given point in a curve. Let G be the point, and GP the tangent. The reading of the plates when sighting G was $\frac{3}{2}D$; clamp at that reading, and transfer the instrument to G , see that the index is not disturbed, and sight to B , then turn off an angle $BGK = GBK$, i.e., $=\frac{3}{2}D$,* or make the reading of the instrument $3D$, and the telescope will point in the direction of the required tangent GK , whence inverting the telescope and making proper deflections as before, other points in the curve may be found. Having run the curve from this new tangent point G , two more stations to E , let us suppose it is desired to turn into tangent at E . Clamp the index at its last reading, that is $4D$, set up at E , and with the index undisturbed observe G , then turn off an angle $GEP = EGP$, the angle deflected from the tangent at the last station, and the telescope will point in the direction of the required tangent.

The following is a general rule for this common operation :

For direction of tangent at any point in a circular curve :

— *From twice the reading of the instrument when locating the point, subtract its reading at the last tangent, or as we sometimes say for shortness, double the index minus the last tangent.*

To illustrate further :—

Suppose the reading of the instrument at G , when the telescope pointed in the direction of GK , to be 12° , the degree of curve being 4° ; then when sighting E , the reading or index will be 16° . Now after making at E the observation on G as

* The student will perceive that the triangle BGK is isosceles.

directed above, turn into tangent by setting the index at $2 \times 16^\circ - 12^\circ = 20^\circ$, and having started at *B* with the index at zero, the reading 20° indicates the magnitude of the central angle *BOE*, or the angle of intersection α .

The student may verify by summing the deflections.

REMARK 1. — It will be perceived that at any tangent point when the telescope points in the direction of the tangent the reading of the vernier gives exactly the amount of the central angle consumed.

Hence, when the angle of intersection, α , of two tangents is measured, the P.C. and P.T. located, and then a curve traced uniting these points, a check on the work is secured, for at the P.T. when the telescope points in the direction of the located tangent, the reading of the plates should be α° .

REMARK 2. — Some engineers before taking the back sight from the new tangent point, turn back the zero of the vernier past the zero of the limb, just as far as it was on the other side when the new tangent point was sighted. Then after sighting the previous tangent point, move the vernier plate back to zero, thus bringing the telescope to point in the direction of the new tangent. But this is objectionable, since it always requires two changes and two readings of the plates, takes more time, it is obviously no more accurate, and moreover renders impossible the convenient check which the more expeditious method introduces.

The following are the field notes of a 3° curve, central angle $25^\circ 30'$, P.C. at station 24, curve turned to the right.

The student should calculate the tangent distance, or find its length 432 feet from Table II. He should also compute the length of the curve $= 8\frac{1}{2}$ stations $= 850$ feet; determine the deflection angle, and the amount to deflect at the P.T. for the sub chord; the reading of the vernier at the tangent points when telescope is pointing in direction of tangent; and in fact he should verify the work in every particular.

	Station.	Deflect.	Reading.	Tangent.	Computed Course.	Magnetic Course.	Remarks.
P.T.	32+50	0° 45'	21° 45'	25° 30'	N 75° 20' E	N 75° 30' E	3° curve, turning right, $\alpha = 25^\circ 30'$ $T = 432.2$ feet.
	32		21° 00'				
	31		19° 30'				
T.P.	30		13° 30'	18° 00'			
	29		12° 00'				
	28		10° 30'				
T.P.	27		4° 30'	9° 00'			
	26		3° 00'				
	25	1° 30'	1° 30'				
P.C.	24	0	0				

Make a complete table, as above, for the following problems —

1. A $3^\circ 40'$ curve, turning right, central angle $48^\circ 40'$, P.C. at station $51 + 60$. Make three tangent points between the P.C. and the P.T.

2. A $9^\circ 30'$ curve to the right, $\alpha = 70^\circ$ P.C. at station 84, make two T.P.'s.

Another method, in which the deflections for all proposed stations may be calculated before going on the field. The record is shown in the table below.

	Station.	Deflection.	Reading.	Computed Course.	Magnetic Course.	Remarks.
P.T.	+50	0° 40'	10° 00'			2° 40' curve, turn'g right. $\alpha = 20^\circ$ $T = 378.9$
	17		9° 20'			
	16		8° 00'			
T.P.	15		6° 40'			
	14		5° 20'			
T.P.	13		4° 00'			
	12		2° 40'			
	11	1° 20'	1° 20'			
	10	0	0			
P.C.						

Set up the transit at station 10, the P.C., and proceed as in the previous case to locate 11, 12, and 13. Carry the transit to 13, clamp the zeros together, and then observe the P.C. Then, if the vernier-plate is moved over 4° in the direction of the curve, the telescope will point in the line of tangent at station 13; and, with the index at $5^\circ 20'$ (the reading oppo-

site 14), station 14 may be set, and $6^{\circ} 40'$ will locate 15. Then transfer the instrument to 15, make the reading 4° (the deflection corresponding to 13, the last T.P.), and observe 13; clamp the lower plate. Now, when the vernier reads $6^{\circ} 40'$, the telescope will point in the direction of the tangent at station 15, and readings of 8° , $9^{\circ} 20'$, and 10° , respectively, will set the remaining stations and sight the P.T. If now the instrument be set up at the P.T. and an observation made on station 15 with the vernier at $6^{\circ} 40'$, the lower plate then clamped, and the reading made 10° , the telescope will point in the direction of the tangent, and this reading is evidently one half the central angle.

REMARK. — Observing T.P. 13 from T.P. 15 *with the index at 4°* , turning into tangent at $6^{\circ} 40'$, and sighting station 16 with the vernier at 8° is evidently the same as though the P.C. were sighted from 15 *with the plates at zero*, the tangent turned at $6^{\circ} 40'$ and station 16 set with the index at 8° . Before making an observation at any station set the vernier at the reading opposite the point on which the observation is to be made, observe the point, clamp the lower plate, then any station in the curve, either way from the instrument, may be located by setting the vernier at the reading opposite that station, and the telescope will point the direction of tangent at the station when the index points to the reading opposite the station.

The advantages which this method possesses over all others are that the deflections required for all proposed stations or known chord lengths may be tabulated in advance, and the deflections may be used to run the curve in from either end, or from any intermediate point, working either way from the instrument. Of course any odd plus employed to locate a point not predetermined will have to be calculated on the field.

62. To locate points in a curve of given radius by offsets from a given tangent.

Let B represent the beginning point; c', e', f' , points in the tangent to be found in order to establish c, e, f , points 100 feet

apart in the curve. The distance from B along the tangent to the points, and the lengths of the offsets are required. From the known radius the angle $BOc = D$ is found, and it is evident that

$$Bc' = mc = R \sin D;$$

$$Be' = m'e = R \sin 2D;$$

and similarly for other points.

Also

$$c'c = Bm = R \text{ versine } D;$$

$$e'e = Bm' = R \text{ versine } 2D;$$

and so on for other points.

From these equations the distances and offsets may be computed, and

then measured off, or they may be taken at once from tables of middle ordinates and long chords, since it will be perceived that the offsets Bm , Bm' , etc., correspond to middle ordinates of double the arcs Bc , Be , etc., and mc , $m'e$, etc., correspond to one-half the long chords of double the arcs. If there is a sub-chord at B the above equations will still give the proper distances by substituting for D the value of the angle, say δ , which the sub-chord subtends, or

$$\begin{aligned} & R \sin \delta, \text{ and for the next point} \\ & R \sin (\delta + D), \text{ and so on.} \end{aligned}$$

The same substitutions will be required in the equations containing the versines.

EXAMPLE.—Find the distances along the tangent and the lengths of the offsets for a curve of 2000 feet radius.

63. To locate a curve of given radius by offsets from chords produced.

Produce the chord ac to e' , Fig. 20, draw bch tangent to the curve at c , and draw ee' through h perpendicular to ch , and suppose a , c , e , and g points in the curve. Then since the angle $e'ch = \text{angle } ech$, and the side ch perpendicular to ee' , these tri-

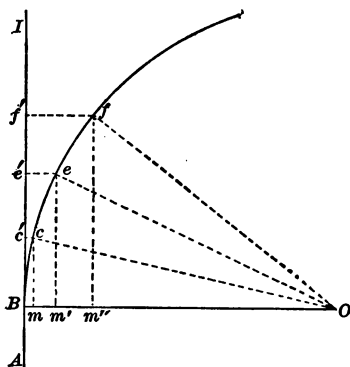


FIG. 19.

angles are equal; the side $ce' = ce$ and the triangle cee' is isosceles. Moreover, since the angle $ece' = cOe$ and both triangles are isosceles, they are similar and the corresponding sides are proportional; hence,

$$\begin{aligned} & cO : ce = ce : ee', \\ \text{or } & R : C = C : ee'; \\ & \therefore ee' = \frac{C^2}{R}. \end{aligned} \quad (26)$$

If $C = 100$, as it does usually, then

$$ee' = \frac{100^2}{R}. \quad (26a)$$

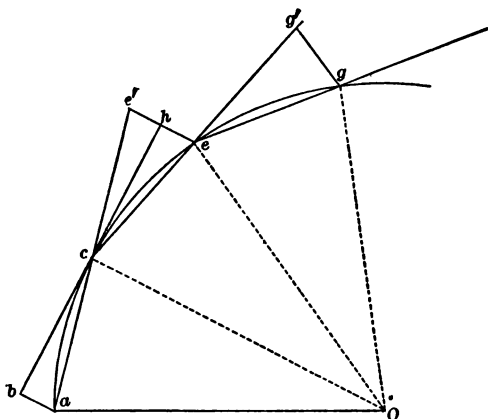


FIG. 20.

Otherwise from the equality of the triangles ceh and $ce'h$, it will be readily perceived that the chord offset $ee' =$ twice the tangent offset he , and therefore the equations for tangent offsets, last articles are applicable. Practically each chord as ac must be extended through c to e' a distance of 100 feet, and then, while preserving the point e' , draw the tape over from e' past h keeping it pivoted at c until the point e is found, which shall be 100 feet from c and the computed distance from e' .

If there is a sub-chord at the beginning, its complement, or what it lacks of 100 feet, may be laid off in the opposite direction by offsets from the tangent, and then having the extremi-

ties of the chord proceed as above. In either case if the chord is not given in this direction find it by offset from tangent, as in article 62.

EXAMPLE. — Given the sub-chord of 30 feet, located in a curve whose radius = 1910 feet, to find the necessary deflections and lay out the curve.

C. OBSTACLES.

64. To pass an obstacle on a curve :

Let O be the center of the curve yx , which we may suppose is laid out in the usual manner by deflection angles, until the point p is reached, when obstacles shown in the figure intervene, requiring evidently some modification or change in the method being employed.

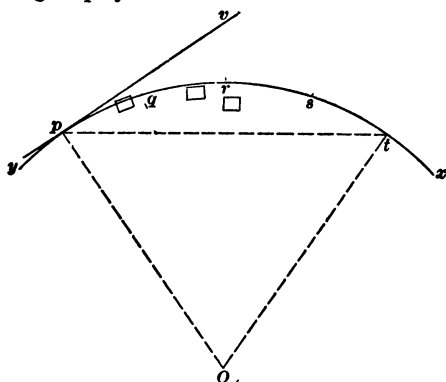


FIG. 21.

The best way ordinarily is to turn off an angle equal to a certain number of deflection angles to just pass the obstacle. In the present case four times one deflection will do ; compute the long chord, as pt , or take its length from table V. Measure out this distance to t , set up there ; turn into tangent, make the proper deflection, and if possible set some of the back stations, as s and r , and then before lifting the instrument locate other points if possible between t and x . Points q and r may be located by offsets from the tangent pv , Art. 62.

65. To locate a curve when the point of intersection is inaccessible.

When the P.I. is inaccessible neither the tangent distance nor the angle α can be measured directly, hence, some equivalent must be discovered.

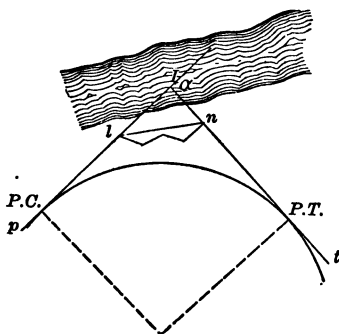


FIG. 22.

The tangents being located as near as practicable to the P.I., set up at some point l in the one, and observe some point n in the other; note the angle nIl , measure ln , and also the angle Inl . The sum of the two angles measured $= \alpha$. From the data obtained compute the distance Il ; measure from l towards p , a distance $=$ to the difference be-

tween the assumed tangent distance and Il , thus locating the P.C., whence the curve may be traced as usual.

If it is impossible to run a straight line, survey a broken line, and, as in working a traverse, determine the direction and length of ln ; then proceed, as before, to find the P.C.

66. To locate a curve when the point of curve is inaccessible.

Let I be a numbered station at the point of intersection of two tangents aI and It , Fig. 23; B , the P.C, the distance to which from I being known. Then if there are two or more stations in the vicinity of a and either of them numbered, the location of any point as c' is discovered; a tangent offset therefrom will fix a point c in the curve extended back of the P.C. Set up at c , and deflect from cc' a right angle less BOc , the telescope will then point in the direction of tangent at c . Then deflect sufficiently to clear the obstacle, usually to some station, measure the long chord cg , and obtain thereby a point in the curve beyond B , whence the curve may be traced in the usual manner. If the preceding is impracticable, set up at some point

I' ; its position may be known by the stakes in tangent or its distance from I may be measured. Compute, and observe the

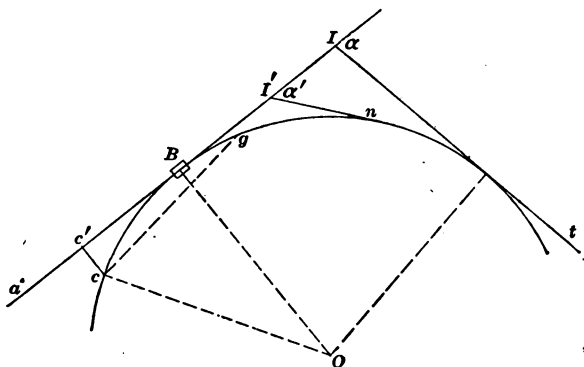


FIG. 23.

angle α' , and measure the distance $I'n = I'B$. Move to n , sight I' , the telescope will then point in the direction of the tangent, and deflections may be made either way to set points in the curve.

67. To locate a curve when both the point of curve and point of intersection are inaccessible.

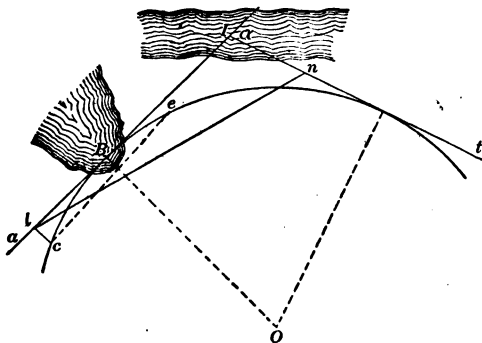


FIG. 24.

Let aI and It represent the tangents. Set up at some point l in the tangent aI ; run a line ln , joining the tangents, as in

point n , and sight from n and measure direct to some point c'' on the tangent, its distance being

$$nc'' = \frac{nn''}{\sin nc''n''}.$$

Then in the triangle $nc''n''$ calculate $c''n''$ and subtract from it $tn'' = R \sin. nOt$, thus obtaining $c''t$, whence the numbering of the stations may be properly continued. If an angle $tn c''$ be turned at n and made one-half $ntn'' =$ one-fourth nOt , tc'' will equal tn'' , and no calculation, except for nc'' , will be necessary.

If the angle at c'' is very acute this method will not be very reliable.

Otherwise, if the obstruction does not prevent alignment.

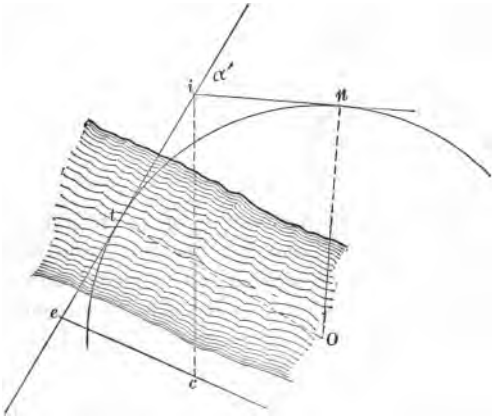


FIG. 26.

From a known point n , in the curve, Fig. 26, compute the tangent distance ni ; measure it off, locate i and set the instrument there. Deflect α' from ni , plunge the telescope and set a point e in tangent; sight another point c along the bank of the stream, measure the angle ec and the length of ec . Then in the triangle cie compute ie , subtract $ti = ni$ from it and thereby obtain te .

Then $BB' = T - T' =$ the given change in tangent distance.
 Draw OD perpendicular to OB , it will equal $T - T'$, and $OD = R - R'$.

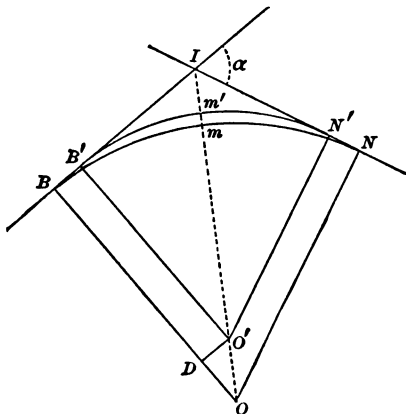


FIG. 28.

Then in the right triangle ODO' ,

$$R - R' = (T - T') \cot. \frac{1}{2} \alpha. \quad (27)$$

From (23) $E = T \tan. \frac{1}{4} \alpha.$

$$E' = T' \tan. \frac{1}{4} \alpha.$$

$$\therefore E - E' = (T - T') \tan. \frac{1}{4} \alpha. \quad (27a)$$

EXAMPLES.

1. Two tangents which intersect at an angle of 32° are united by a $3^\circ 30'$ curve. It is desired to lengthen the tangent distance 72 feet; find the necessary change in R and E .

By (27) $R - R' = 72 \cot 16^\circ,$
 $R - R' = 72 \times 3.2709 = 237.5;$
 $\therefore R = 1637.28 + 237.5 = 1874.78,$

or a curve of about $3^\circ 3'.$

By (27a) $E - E' = 72 \tan 8^\circ,$
 or $E - E' = 72 \times 0.1405 = 10.12.$

2. Find the change in the degree of curve in Example 1, on the assumption that T is to be shortened 60 feet.

71. Having located a curve between two tangents it is required to determine the necessary change in the radius and tangent distance, for any desired change in the external distance. (Fig. 28.)

$$\begin{aligned}\text{By (19)} \quad mI &= E = R \operatorname{exsec} \frac{1}{2} \alpha, \\ m'I &= E' = R' \operatorname{exsec} \frac{1}{2} \alpha;\end{aligned}$$

$$\text{or,} \quad R - R' = \frac{E - E'}{\operatorname{exsec} \frac{1}{2} \alpha} \quad (28)$$

$$\text{By (27a)} \quad T - T' = (E - E') \cot \frac{1}{2} \alpha. \quad (29)$$

EXAMPLE. — Two tangents which intersect at an angle of 40° are united by a $3^\circ 40'$ curve. It is desired to bring the middle point of the curve 30 feet nearer the P.I. Find the length of R' and T' .

$$\text{By (28)} \quad R - R' = \frac{30}{\operatorname{exsec} 20},$$

$$R - R' = \frac{30}{.0642} = 467.29.$$

$$\therefore R' = 1562.88 - 467.29 = 1095.59,$$

or a curve of $5^\circ 14'$

$$\text{By (29)} \quad T - T' = 30 \cot 10,$$

$$T - T' = 30 \times 5.6713 = 170.14.$$

$$\therefore T' = 568.84 - 170.14 = 398.7.$$

72. Having located a curve between two tangents it is required to determine the necessary change in the tangent distance and external distance for any desired change in the radius.

From (27) we obtain

$$T - T' = (R - R') \tan \frac{1}{2} \alpha. \quad (30)$$

$$\text{From (28)} \quad E - E' = (R - R') \operatorname{exsec} \frac{1}{2} \alpha. \quad (31)$$

EXAMPLE. — Two tangents which intersect at an angle of $28^\circ 40'$ are united by a $4^\circ 20'$ curve. Find what change would be made in T and E , by the substitution of a 5° curve.

73. Having located a curve between two tangents it is required to determine the radius of a curve which from the same point of curve will terminate in a defined parallel tangent.

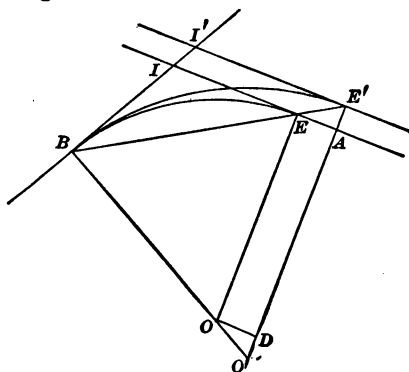


FIG. 29.

Let BE represent the located curve and BE' the curve required.

Since the tangents EI and $E'I'$ are parallel the angles OBE , OEB and $O'E'B$ are equal, the central angle α remains unchanged, and EE' is a prolongation of the chord BE .

Denote AE' the perpendicular distance between the tangents by d , and draw OD perpendicular to the

radii $OE = R$ and $O'E' = R'$;

$$\text{Then} \quad OD + DA + AE' = R',$$

$$\text{or,} \quad (R' - R) \cos \alpha + R + d = R',$$

$$\text{and} \quad R' (1 - \cos \alpha) = R (1 - \cos \alpha) + d,$$

$$\text{whence} \quad R' = R + \frac{d}{\text{versine } \alpha}. \quad (32)$$

In practice, before removing the instrument from E , the distance and direction to E' should be computed and a stake driven there to serve as a check on the location of the curve BE' .

The student will observe that

$$EE' = d \cdot \sec \frac{180 - \alpha}{2},$$

$$\text{or,} \quad EE' = d \cdot \text{cosec } \frac{\alpha}{2}. \quad (33)$$

and the angle which EE' makes with AE is $\frac{1}{2} \alpha$.

If BE' represents the located curve and BE the curve required, then R' will be known and R required.

$$\text{or,} \quad R = R' - \frac{d}{\text{versine } \alpha}. \quad (34)$$

If it is determined on the ground through what point in the prolongation of the chord BE , as E' , the tangent must pass; then measure d' the distance from E to E' , and proceed otherwise, as before —

$$R' = (R' - R) \cos \alpha + R + d' \sin \frac{\alpha}{2},$$

$$\text{or,} \quad R' = R + \frac{d' \sin \frac{\alpha}{2}}{1 - \cos \alpha},$$

$$\text{whence} \quad R' = R + \frac{d'}{2 \sin \frac{1}{2} \alpha} \left[\text{since } 1 - \cos \alpha = 2 \sin^2 \frac{\alpha}{2} \right]. \quad (35)$$

If the parallel tangent is on the center side of the terminal tangent.

$$R = R' - \frac{d'}{2 \sin \frac{1}{2} \alpha}. \quad (36)$$

The student may find an expression for R' in terms of the chords, BE , BE' and R .

EXAMPLE. — A $3^\circ 30'$ curve having a central angle of $34^\circ 40'$ ends in a tangent IE . It is required to substitute a curve having the same P.C. but to terminate in a parallel 16 feet from IE .

74. Having located a curve between two tangents, it is required to determine the change in the point of curve so that, with the same radius, the curve may end in a given parallel tangent.

The required curve as to size and shape, is the given curve in another position; its elements are precisely the same. Imagining the one to merge into the other, it will be perceived that as B Fig. 29a, approaches B' , O will approach O' , and N and I respectively N' and I' . Hence the lines joining these like-lettered points, are equal and parallel. Therefore turn off from the ter-

minal tangent at N , an angle $= \alpha^\circ$, and measure in the direction of the telescope to a point N' in the given parallel tangent. This distance laid off from B will give the position of the new P.C.

If the perpendicular distance NK between the parallel tangents is given, then in the triangle $NN'K$, observing that the angle $NN'K = \alpha$ and putting $NK = d$.

$$NN' = BB' = d \operatorname{cosec} \alpha. \quad (37)$$

As in the preceding case the direction of B' from B is dependent upon the relative position of the terminal and parallel tangents.

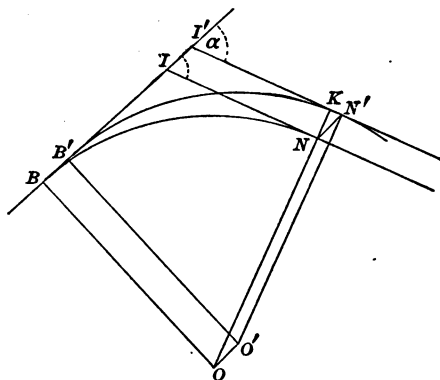


FIG. 29a.

EXAMPLE. — A $4^\circ 20'$ curve having a central angle of $32^\circ 40'$ ends in the tangent IN . Compute the distance the P.C. must be advanced along BI so that with the same radius the curve may be run ending in a tangent parallel to IN , and 16 feet farther from the centre.

$$BB' = 16 \cdot \operatorname{cosec} 32^\circ 40'.$$

$$BB' = 16 \times 1.8527 = 29.64.$$

75. Having located a curve between two tangents, it is required to change the radius and the point of curve, so that the curve may terminate in a given parallel tangent at a point on the same radial line as the first.

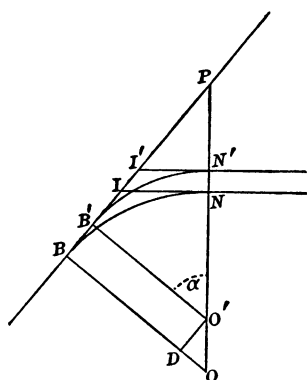


FIG. 30.

Let IN be the located tangent, and $I'N'$ the given parallel tangent, O and O' the corresponding centers of curvature, and R and R' the radii. Drop a perpendicular from O' on OB , prolong the tangent BI and radius ON to their intersecting point P , and denote the distance NN' on the radial line by d .

Then $PN - PN' = d$,

or $(R - R') \operatorname{exsec} \alpha = d$;

whence $(R - R') = \frac{d}{\operatorname{exsec} \alpha}$, (38)

and
$$R' = R - \frac{d}{\operatorname{exsec} \alpha}. \quad (39)$$

$$BB' = DO' = (R - R') \tan \alpha, \quad (40)$$

or substituting the value of $R - R'$ from (38)

$$BB' = \frac{d \tan \alpha}{\operatorname{exsec} \alpha}.$$

But $\tan \alpha = \operatorname{exsec} \alpha \cot \frac{1}{2} \alpha$,

$$\therefore BB' = d \cotg \frac{1}{2} \alpha. \quad (41)$$

76. Having located a curve between two tangents, it is required to find the change in the point of curve consequent upon a given change in the direction of the terminal tangent at the point of intersection, the radius remaining the same.

Denote BI and $B'I$ Fig. 31 by T and T' respectively, and the angles NOB and $N'O'B'$ by α and α' respectively.

Then
$$BB' = T - T' = R (\tan \frac{1}{2} \alpha - \tan \frac{1}{2} \alpha'). \quad (42)$$

If the position of the P.C. remains fixed and R change, the other condition as above in this article, find the new radius.

Calling α and α' the angles of intersection, R and R' radii, and T the length of the tangent. We shall have

$$T = R \tan \frac{1}{2} \alpha,$$

$$\text{and } T = R' \tan \frac{1}{2} \alpha',$$

whence

$$R' = R \tan \frac{1}{2} \alpha \cot \frac{1}{2} \alpha'. \quad (43)$$

The student may supply the figure.

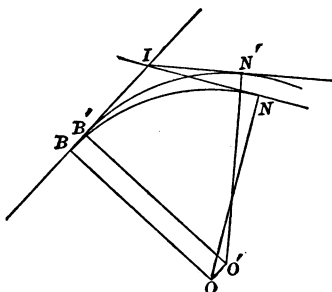


FIG. 31.

EXAMPLES.

1. Given a $3^\circ 40'$ curve, the angle of intersection $28^\circ 20'$, to find the position of the P.C., if the terminal tangent IN' makes an angle of 6° with IN ; the radius remaining the same length.

2. Given the same degree of curve, and α as in the last example, to find the change in the radius, so that the position of the P.C. may remain unchanged if α be diminished 6° .

77. Having located a curve between two tangents, it is required to change the radius and the point of curve so that the terminal tangent may be changed in its direction at the point of tangent.

Let IN represent the located tangent; $I'N$ the terminal tangent; INI' the given change in the angle at N . The student may show that $\alpha' = \alpha + INI'$; that

$$R' = \frac{R \operatorname{versine} \alpha}{\operatorname{versine} \alpha'} \quad (44)$$

$$\text{and } BB' = R \sin \alpha - R' \sin \alpha'. \quad (45)$$

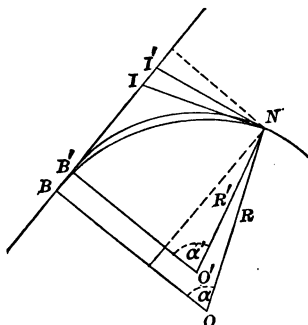


FIG. 32.

CHAPTER IV.

COMPOUND CURVES.

A. PROBLEMS IN LOCATION.

78. Given two tangents of unequal length, their angle of intersection, and one radius, to find the length of the radius of the other branch of a compound curve which will unite the tangents.

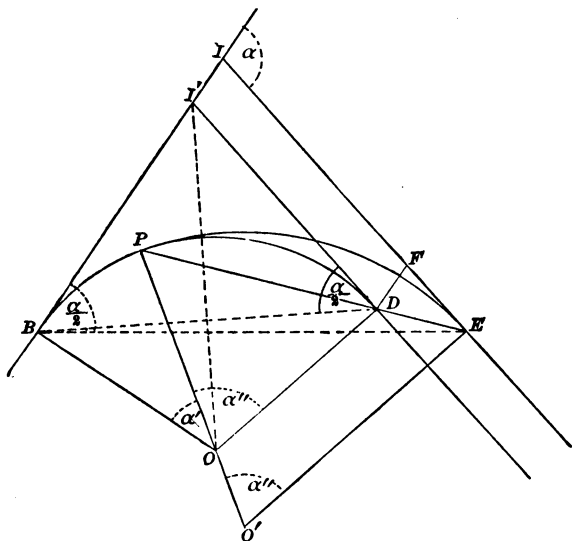


FIG. 33.

Let BPE represent the curve.

Denote the radii PO and PO' by R and R' respectively.

- “ tangents BI and IE by T and T' “
- “ angles BOP and $PO'E$ by α' and α'' “
- “ angle of intersection by α .

Extend the first branch of the curve to D , where its terminal tangent is parallel to the tangent IE , and draw DF parallel to BI . Draw the chord PE , it will pass through D . Draw also OI' and BD . In the triangle DEF , DF is equal to II' by construction, and, therefore,

$$DF = T - R \tan \frac{1}{2} \alpha,$$

$$FE = T' - R \tan \frac{1}{2} \alpha,$$

and angle

$$F = 180^\circ - \alpha,$$

whence the angle FED and side ED may be found. Now $2 \angle FED = \alpha''$, and hence $\alpha' = \alpha - \alpha''$ becomes known.

Again

$$2R \sin FED = PD,$$

$$2R' \sin FED = PE,$$

Therefore

$$2R' \sin FED = 2R \sin FED + DE,$$

whence

$$R' = R + \frac{DE}{2 \sin FED}. \quad (46)$$

The point D may be located by turning off half α° from the P.C. on tangent BI , and measuring the corresponding long chord. Then, having computed the angle FED , set up the instrument at D , turn off from the parallel tangent through D the angle FED , and thereby locate P , the P.C.C., and E , the P.T., after which in the usual manner the curve may be staked out.

EXAMPLES.

1. Given BI and EI 500 and 600 feet respectively, their angle of intersection $21^\circ 40'$, and the radius of the first branch 2500 feet. Find the radius of the second branch, and number the P.C.C. and P.T., assuming the P.C. to be $24 + 60$.

2. The student may reason out by aid of a diagram the case where the length BI is greater than EI , and the given radius of the first branch is the longer; and verify his deductions by numerical example and construction.

79. Given the length of the straight line between the P.C. and the P.T., the angles which it makes with the tangents, and the radius of the first branch, to find the radius of the second branch of a compound curve uniting the tangents.

In Fig. 33 let d denote the distance from B to E , B and E the angles, at the respective points, between the chord and the

tangents, R and R' the radii of the first and second branches respectively, and α' and α'' as shown in the figure. The angle $IBD = \frac{1}{2}\alpha = \frac{1}{2}(B + E)$. In the triangle BDE , BE is given, $BD = 2R \sin \frac{1}{2}(B + E)$ and the angle $DBE = B - \frac{1}{2}(B + E) = \frac{1}{2}(B - E)$. Therefore the angle BED and side DE can be computed, and $E - BED =$ the angle which the chord PDE makes with the tangent IE , and thus α'' and α' become known. Then, as before, using the relation between an angle, its subtended chord, and radius, the value may be found of

$$R' = R + \frac{DE}{2 \sin PEI}, \quad (47)$$

which agrees with (46).

80. Given the radii and the central angles of a compound curve uniting two tangents, to find the lengths of the tangents, the line connecting the P.C. and P.T., and the angles which this line makes with the tangents.

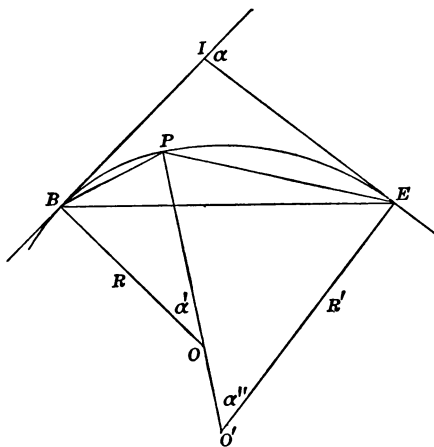


FIG. 34.

In Fig. 34 let B and E represent the P.C. and P.T. respectively, P the P.C.C., O and O' the centers, IB and IE tangents, d the connecting line, and other notation as shown in the figure. With the given central angles and radii compute the lengths of the chords BP and PE ; find also the angles $OPB =$

OBP and $O'PE = O'EP$. Then in the triangle BEP find the angles PBE and PEB and the side $BE = d$. The unknown angles may now be found as follows:—

The angle $EBI = 90 - PBO + PBE$.

The angle $BEI = 90 - PEO' + PEB$.

Then in the triangle BEI having all the angles and the side d , compute the tangents BI and IE .

EXAMPLE. — Given R , 1432.7 feet, R' , 2148.8 feet α' , 20° and α'' , 45° ; to find the lengths of the tangents, the line BE , and the angles which the tangents make with BE .

81. Given the length of the straight line between the P.C. and the P.T., and the angles which it makes with the tangents, it is required to find the radii of a compound curve having the common tangent parallel to the straight line.

In the figure let DF represent the tangent parallel to the given line BE . P the P.C.C., DBE and FEB the given angles, and d the length of BE .

It is evident that $DB = DP$; and $FE = FP$ and the angles DBP and $FEP = \frac{1}{2} B$ and $\frac{1}{2} E$ respectively.

In the triangle BEP we have the proportion

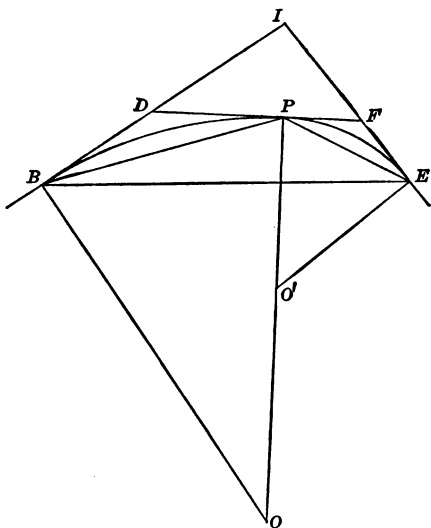


FIG. 35.

$$BP : BE = \sin BEP : \sin [180 - \frac{1}{2}(B + E)],$$

or,
$$BP = \frac{d \sin \frac{1}{2} E}{\sin \frac{1}{2} (B + E)},$$

and
$$PE = \frac{d \sin \frac{1}{2} B}{\sin \frac{1}{2} (B + E)}.$$

possible; calculate the chord B_1m , parallel to the common tangent through P , and the length of the middle ordinate mP for double the arc B_1P . Then in the second branch find the angle β'' having the same middle ordinate mP , for double its arc, whence the length of the chord mE , may be computed.

Then deducting $\alpha' + \beta''$ from α the angle $E_1O'E$ will be obtained, and thence the distance to the P.T.

If the curves are much obstructed, so that few, or no stakes, can be set in them, run direct from the P.C. to some point on the second branch — obtaining the necessary data, as indicated in the foregoing. Or, if it is more practicable, run the common tangent APD .

The length of this line can readily be found, since $AP = AB$ and $PD = DE$ are tangent distances, by applying the well-known rule: — Radius multiplied by tangent of one-half the central angle is equal to the tangent distance.

EXAMPLES.

1. Given $\alpha' = 12^\circ$, $\alpha'' = 10^\circ 30'$, and the degrees respectively 3 and 5 to locate the P.T., the P.C.C. being obstructed by a building:

$$BA = AP = 1910 \tan 6^\circ = 201.6 \text{ feet,}$$

$$PD = DE = 1146 \tan 5^\circ 15' = 105.3 \text{ feet.}$$

With the instrument at B , set as many stakes as possible on the curve BP , then sight along the tangent and measure BA 201.6 feet; remove to A , turn off the angle α' , and measure AD 306.9 feet, offsetting at P . With the instrument at D , turn off the angle α'' as indicated in the figure, and measure DE 105.3 feet to the P.T. Having now located the P.T., if practicable, set one or two stakes in the curve EP .

The student may determine where to place these last stakes and how to number them, that they may appear consecutive, the P.C. being at number 42. State also the *plus* of the P.T.

2. Given a 2° and a 4° curve, α' and α'' respectively 9° and 13° , conditions favorable to setting the first three stakes on

first branch, and from the third station run a parallel to the common tangent past the obstacle. Show how to continue the work, find the point where the parallel line intersects the second branch, the reading of the instrument at this point when telescope sights the tangent, supposing the index was at zero at the P.C., and find the plus of the P.T., calling the P.C. $17 + 40$.

C. PROBLEMS IN CHANGE OF LOCATION.

83. Having located a compound curve terminating in a tangent, it is required to change the location, so that, with the same radii, the curve may end in a parallel tangent at a given perpendicular distance from the terminal tangent.

FIRST CASE.—The parallel tangent farther out than the terminal tangent, and the second branch of the curve having the longer radius.

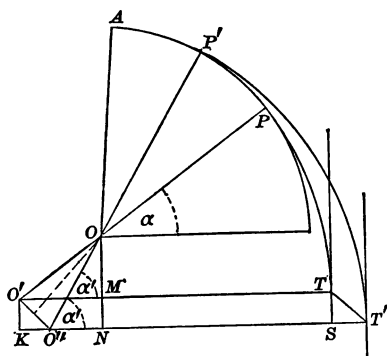


FIG. 37.

The figure opposite represents the case. The first curve with center O having been run from A , compounded at P into one with radius $O'P$, and terminating in a tangent at T . It is desired to locate the tangent further out at a given perpendicular distance from the present one. It is

evident that the P.C.C. must be moved back on the sharper curve to some point P' . The practical question is to find this point.

Let $O'P'$ represent the required position of the longer radius, and draw OMN perpendicular to the radii OT and $O'T'$. It is evident that the angle POP' is equal to $\alpha' - \alpha = \angle OO'N - \angle OO'M$, and as the latter is known we may find the former as follows:—

Let R denote the radius of the first branch of the curve.

“ R' “ “ “ “ second “ “ “

“ α “ “ angle “ OOM .

“ α' “ “ “ “ $OO'N$.

“ d “ “ perpendicular distance between the tangents.

Then $(R' - R) \cos \alpha = OM$,

and $(R' - R) \cos \alpha' = O'N$.

But $OM - O'N = d$ substituting we obtain

$$(R' - R) \cos \alpha - (R' - R) \cos \alpha' = d,$$

$$\text{or,} \quad \cos \alpha' = \cos \alpha - \frac{d}{R' - R} \quad (50)$$

$$\text{and} \quad \alpha' - \alpha = POP'.$$

Divide $\alpha' - \alpha$ by the degree of the first branch and thus ascertain the distance from P to P' .

To find the distance and direction of T' from T ; connect the points $O'O''$, and draw a perpendicular from O to the line $O'O''$; also draw the perpendicular $O'K$ on the radius $O'T'$ prolonged. Then, evidently,

$$TT' = O'O'' = 2(R' - R) \sin \frac{1}{2}(\alpha' - \alpha). \quad (51)$$

Now considering the angles about the point O' , we perceive that

$$90 + \alpha = KO'O'' + 90 - \frac{1}{2}(\alpha' - \alpha),$$

$$\text{or,} \quad KO'O'' = \alpha + \frac{1}{2}(\alpha' - \alpha);$$

$$\therefore \text{angle } STT' = KO'O'' = \frac{1}{2}(\alpha' + \alpha). \quad (52)$$

With the instrument then at T , turn off from the tangent an angle equal to the arithmetical mean of the given and computed angles; the telescope will then point in the direction of the new P.T. Measure off the distance computed by (51); set, and center a stake there before running in the new curve.

REMARK. — This method, based on the arithmetical mean, for obtaining direction between the tangent points, holds true for all four of the cases coming under this head. It was suggested by Mr. Edward Godfrey, Class of '93, W.U.P.

EXAMPLE. — Given a 5° curve compounding into a $2^\circ 40'$ for $12^\circ 50'$, and terminating in a tangent; it is desired to move the tangent out 10 feet. Ascertain the change necessary in the P.C.C. Ans. 47 feet towards P.C.

THIRD CASE.—The parallel tangent farther out than the terminal tangent, and the second branch of the curve having the shorter radius.

It is evident that the *flatter* branch must be lengthened at the expense of the sharper one, and, as before, the angle POP' must be determined in order to locate P' .

Denote the angle OOM by α , $O'ON$ by α' , and R and R' , the radii of the first and second branches respectively.

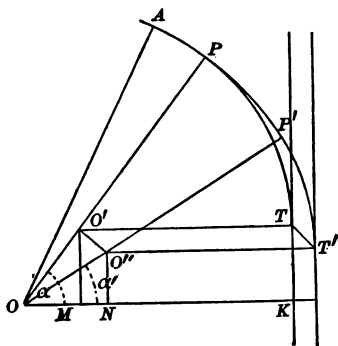


FIG. 39.

Then $(R - R') \cos \alpha' = (R - R') \cos \alpha + d,$

or, $\cos \alpha' = \cos \alpha + \frac{d}{R - R'},$ (56)

and $\alpha - \alpha' = POP'.$

Whence the distance PP' may be found as before, and the first branch extended.

The distance between the tangent points may be determined as in the second case thus,

$$TT' = OO' = 2(R - R') \sin \frac{1}{2}(\alpha - \alpha'). \quad (57)$$

The student may show that the direction of T' from T is obtained, as in the other cases, by deflecting from the tangent at T , $\frac{1}{2}(\alpha + \alpha')$.

EXAMPLE.—Given a $3^{\circ} 20'$ curve compounding into a $5^{\circ} 40'$ for 22° , and terminating in a tangent. It is desired to have the tangent 16 feet farther out. Locate the new P.C.C., and the new P.T., and state the length of the curve required.

FOURTH CASE.—The parallel tangent farther in than the terminal, and the second branch of the curve having the shorter radius.

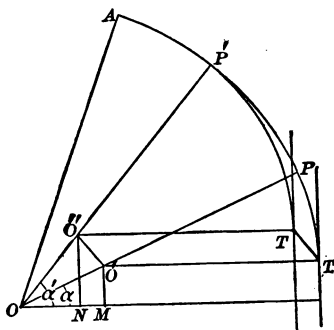


FIG. 40.

Adopting the notation of the third case (R' = radius of second branch) we have

$$(R - R') \cos \alpha' = (R - R') \cos \alpha - d,$$

$$\text{or,} \quad \cos \alpha' = \cos \alpha - \frac{d}{R - R'}, \quad (58)$$

$$\text{and} \quad \alpha' - \alpha = POP'.$$

Whence the distance from P to P' , the new P.C.C., is readily obtained.

The distance between the tangent points is shown by the equation

$$TT' = OO' = 2(R - R') \sin \frac{1}{2}(\alpha' - \alpha). \quad (59)$$

and the angle to be turned off from the tangent at $T = \frac{1}{2}(\alpha' + \alpha)$.

EXAMPLE.—Given a 2° curve compounding into a 3° for 10° , and terminating in a tangent. It is desired to move the tangent in 12 feet. Show that the P.C.C. has to be moved 176.5 feet, and give the direction and distance of the new P.T. from T .

84. A method of solution, similar to the preceding, may be applied to the following problem:

Given a simple curve AT terminating in a tangent at T ; it is required to find the point P , at which, by compounding with a curve of known radius, the curve may end in a given parallel tangent.

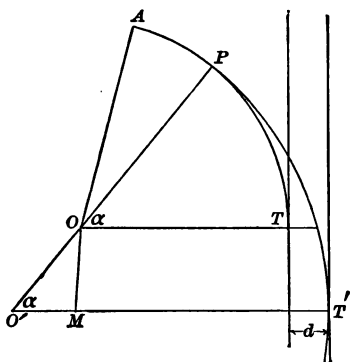


FIG. 41.

Denote the unknown angle POT by α ,
 “ perp. dist. between tangs. by d ,
 “ first radius OT by R ,
 “ second radius $O'T'$ by R' .

Then $OO' \cos \alpha = O'M$,
 or, $(R' - R) \cos \alpha = R' - (R + d)$;

whence $\cos \alpha = 1 - \frac{d}{R' - R}$. (60)

EXAMPLES.

1. Given a $5^\circ 20'$ curve terminating in a tangent at T ; it is required to locate a point P , whence a $3^\circ 30'$ curve may be run which shall end in a parallel tangent 18' farther out. *Ans.* $\alpha = 14^\circ 32'$, and distance from T to the P.C.C. = 272.5 ft.

Solve the following, making such modifications of the preceding formula as may be necessary.

2. Given a $2^\circ 40'$ curve terminating in a tangent; it is required to locate a point P , whence a $4^\circ 20'$ curve may be run which shall end in a parallel tangent 16' farther in.

85. Having located a compound curve terminating in a tangent, it is required to change the P.C.C. and the radius of the second branch, so that the curve may end in a parallel tangent at a given point on the same radial line.

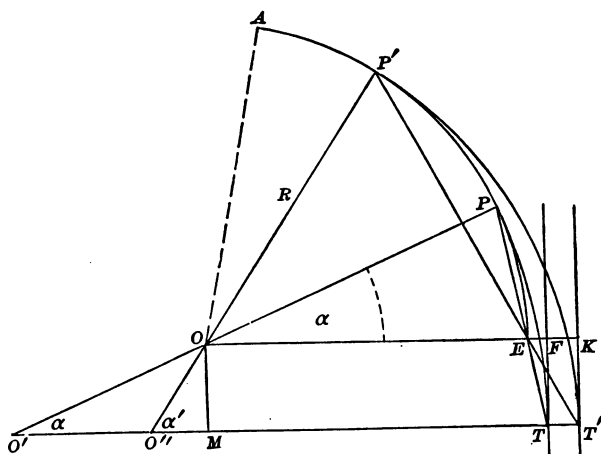


FIG. 42.

FIRST CASE. — The parallel tangent outside the terminal tangent, and the second branch of the curve having the longer radius.

Let APT be the located curve, and $AP'T'$ the required curve, having the centers O and O' respectively, and P' the new point of compound curvature.

Let $R = OP$, the radius of the first branch,

" $R' = O'P$, " " second "

" $R'' = O''P'$ " " required "

" d = the given distance between tangents,

and the angles as indicated in the figure.

Extend the first branch of the curve from P till it terminates at E in a tangent parallel to the terminal tangent TF . Draw the radius OE , and with the radius $O'P'$ describe the arc $P'T'$. The angle POE being equal to POT , the chord PT will pass through E ; and the angle $P'OE$ being equal to

$P'O'T'$, the chord $P'T'$ will also pass through E . The point P' may, therefore, be constructed by extending the chord from T' through E till it meets the first branch.

There are two principal steps in the solution.

First to find α' , and with it, *second*, to find R'' .

To find α' the figure shows that the angle $P'T'K$ is equal to $\frac{1}{2}\alpha'$, hence,

$$\tan \frac{1}{2}\alpha' = \frac{EK}{T'K} = \frac{EF}{TF} + \frac{d}{T'K}.$$

But $\frac{EF}{TF} = \tan \frac{1}{2}\alpha$ and $T'K = TF = OM = (R' - R) \sin \alpha$.

Substituting, there results,

$$\tan \frac{1}{2}\alpha' = \tan \frac{1}{2}\alpha + \frac{d}{(R' - R) \sin \alpha}. \quad (61)$$

In the triangle $OO'O''$, by the law of sines OO'' may be found, which added to OP' , will give the length of R'' .

Or, in the triangles $OO'M$ and $OO''M$ find at once

$$(R'' - R) \sin \alpha' = (R' - R) \sin \alpha;$$

whence $R'' = (R' - R) \frac{\sin \alpha}{\sin \alpha'} + R. \quad (62)$

SECOND CASE. — **The parallel tangent inside of the terminal tangent and the second branch having the longer radius.** Using the same figure and notation as in the preceding, α and R' become the unknown quantities, and we have

$$\tan \frac{1}{2}\alpha = \frac{EK - d}{T'K},$$

or, $\tan \frac{1}{2}\alpha = \tan \frac{1}{2}\alpha' - \frac{d}{(R'' - R) \sin \alpha'}, \quad (63)$

and $R' = (R'' - R) \frac{\sin \alpha'}{\sin \alpha} + R. \quad (64)$

EXAMPLES.

1. Given a $5^\circ 20'$ curve compounded at P , Fig. 42, into a $2^\circ 40'$ and terminating in a tangent FT at T , making $\alpha 16^\circ 30'$; it is required to end in a parallel tangent KT' intersecting the prolongation of OT 18 feet farther out. Find P' , and $O'P'$, the new P.C.C. and radius respectively.

FOURTH CASE. — The parallel tangent inside the terminal tangent and the second branch having the shorter radius.

Using the same notation as in the preceding case, α and R become the unknown quantities, and we have

$$\tan \frac{1}{2} \alpha = \frac{EF + d}{TK},$$

$$\text{or,} \quad \tan \frac{1}{2} \alpha = \tan \frac{1}{2} \alpha' + \frac{d}{(R - R'') \sin \alpha'}, \quad (67)$$

$$\text{and} \quad (R - R'') \sin \alpha' = (R - R') \sin \alpha;$$

$$\text{whence} \quad R' = R - (R - R'') \frac{\sin \alpha'}{\sin \alpha}. \quad (68)$$

EXAMPLES.

1. Given a $2^\circ 50'$ curve, compounded at P , Fig. 43, into a $4^\circ 50'$, and terminating in a tangent at T , making $\alpha 30^\circ$; it is required to end the curve in a parallel tangent intersecting the prolongation of $O'T$ at T' , 24 feet distant from T . Find P' and the length of $O'P'$.

2. Given a $2^\circ 40'$ curve compounded into a $4^\circ 40'$, and terminating in a tangent, making $\alpha' 24^\circ$; it is required to end in a parallel tangent, intersecting the same radius 20 feet farther in. Locate the new P.C.C., and determine the radius of the last branch.

86. Having located a compound curve between two tangents, it is required to shift the P.C.C. and change the radius of the last branch so that the curve may end at some other point in the terminal tangent.

FIRST CASE. — When the second branch of the curve has the longer radius and the point in the tangent is given as at E' .

In the figure there are given the central angles at O , and O' , the radii drawn from these points, and the distance d between E and E' . It is required to find the angle at O'' and the radius $O'E'$.

Extend the first branch of the curve to D , where its terminal tangent becomes parallel to IE ; draw the chord PE ; it will pass through D , and the line drawn from E' through D prolonged to the curve will indicate at P' the new P.C.C. (See Art. 73.) Finally draw from O , the line OMN perpendicular to R' and R'' , and with center O' describe the arc OQ .

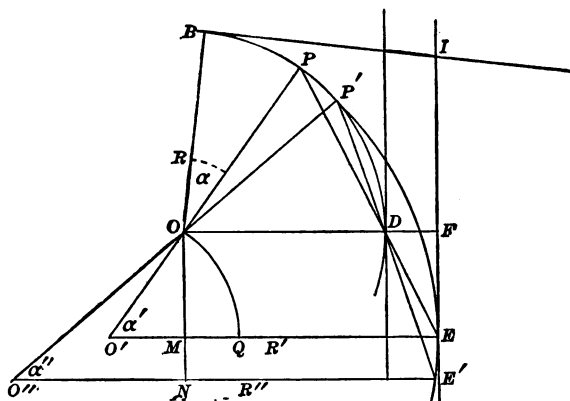


FIG. 44.

By construction $DF = MQ$.

$$\begin{aligned} \therefore DF &= (R' - R) (1 - \cos \alpha') \\ &= (R' - R) \text{versine } \alpha'. \end{aligned} \quad (69)$$

In the triangles DEF and $DE'F$,

$$\cot \frac{\alpha'}{2} = \frac{EF}{DF}, \text{ and } \cot \frac{\alpha''}{2} = \frac{E'F}{DF};$$

whence, by substitution,

$$\cot \frac{\alpha''}{2} = \cot \frac{\alpha'}{2} + \frac{d}{DF},$$

$$\text{or, } \cot \frac{\alpha''}{2} = \cot \frac{\alpha'}{2} + \frac{d}{(R' - R) \text{versine } \alpha'}. \quad (70)$$

Divide $\alpha' - \alpha''$ by the degree of curve of first branch, and the result will show how far to extend the first branch to reach the new P.C.C.

In the triangles OOM and $OO''N$,

$$(R' - R) \sin \alpha' = OM,$$

$$(R'' - R) \sin \alpha'' = ON,$$

or, by subtraction,

$$(R'' - R) \sin \alpha'' - (R' - R) \sin \alpha' = MN = d;$$

whence,
$$R'' = R + \frac{(R' - R) \sin \alpha' + d}{\sin \alpha''}. \quad (71)$$

Assuming the terminus of the curve at E' , write the equations for α' and R' so that the P.T. may be at E , d distance from E' .

SECOND CASE. — **Conditions the same as in the preceding, except the point is not definitely located; it must be, however, somewhere on the terminal tangent.**

Here we may assume new central angles, that is, a new P.C.C., and calculate R'' ; or, we may assume R'' , and compute the change in the angles. The student may show that, assuming the P.C.C.,

$$R'' = R + \frac{DF}{\text{versine } \alpha''}, \quad (72)$$

and, assuming R'' ,

$$\text{versine } \alpha'' = \frac{DF}{R'' - R}. \quad (73)$$

Show also how to find the distance d in each of the examples of this case, so that in practice a check may be had on the work.

EXAMPLE. — Having located a compound curve terminating in a tangent, the radii of the first and second branches respectively, 1600 and 2500 feet, and the angle $\alpha = 32^\circ$; it is required to move the P.C.C. back 150 feet. Find the radii of a curve which shall end somewhere in the terminal tangent, and locate the new P.T.

87. To substitute a three-centred compound curve for a simple curve.

In the figure let α denote the central angle at O , α' the angle at O' , R, R', R'', R'' , the radii, the last two being equal, and sweeping equal arcs PE and BP . It is evident that

the intersection O' of the radii $R''R''$ will be on the line bisecting the simple curve, and O' is, therefore, the center of the middle part of the compound curve, $O''O'''$ being centers of the other parts, and $\alpha =$ the sum of the angles at the centres O, O' and O''' .

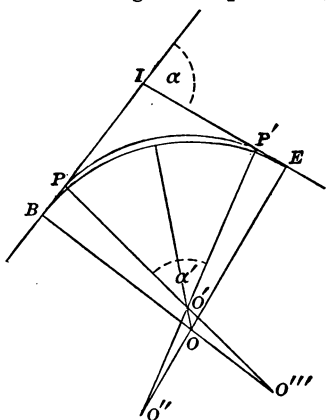


FIG. 45.

In practice we assume the radii R' and R'' , or, R' and the equal angles at O' and O''' , and compute what is required.

Proceeding under the first assumption, and using the triangle O, O', O''' (O, O', O''' would answer as well), we have the proportion,

$$R'' - R' : R'' - R = \sin \frac{\alpha}{2} : \sin \frac{\alpha'}{2};$$

whence,

$$\sin \frac{\alpha'}{2} = \sin \frac{\alpha}{2} \frac{(R'' - R)}{(R'' - R')}, \quad (74)$$

and the angle at

$$O'' = O''' = \frac{\alpha - \alpha'}{2}. \quad (75)$$

Under the second assumption we find from the above proportion,

$$(R'' - R) \sin \frac{\alpha}{2} = (R'' - R') \sin \frac{\alpha'}{2};$$

whence,

$$R'' = \frac{R \sin \frac{\alpha}{2} - R' \sin \frac{\alpha'}{2}}{\sin \frac{\alpha}{2} - \sin \frac{\alpha'}{2}}, \quad (76)$$

α' being known, since all the other angles are given.

EXAMPLE. — Given, $R = 1910$, $\alpha = 36^\circ$,
 $R' = 1508$, $R'' = 5730$.

Find $EP' = PB$.

Ans. 177 ft.

CHAPTER V.

MISCELLANEOUS PROBLEMS.

88. Given a simple curve intersected by a straight line; it is required to find a point on the curve from which to run a curve of given radius that shall terminate in the straight line as a tangent.

FIRST CASE.—**The P.T. on the straight line inside of the given curve.** Let BE represent the curve, TN the straight line, and N the point of intersection. Measure forward and backward from N to points equidistant on the curve; bisect the line connecting these points, and thus obtain the direction of the radius ON . Or, more accurately, with the instrument at N and the reading zero, direct the telescope to a point in the curve 100 feet distant, and turn off from the curve an angle equal to one-half the degree of the curve, then the telescope will point in the direction of the tangent NG . Observe the angle ONT . Suppose the curve produced to E' where its terminal tangent becomes parallel to the given line NT , draw $O'M$ perpendicular to OE' . Denote the radii of the given and required curves by R and R' respectively, the known angle NOT by α , and the required angle $PO'P'$ by β . P being the point sought.

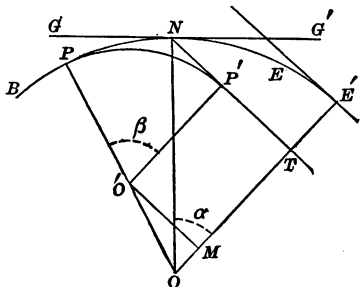


FIG. 46.

It is evident from the figure that,

$$R \cos \alpha = (R - R') \cos \beta + R';$$

or

$$\cos \beta = \frac{R \cos \alpha - R'}{R - R'}, \quad (77)$$

and

$$\beta - \alpha = \text{angle } PON,$$

whence P may be located, and the curve PD set out.

SECOND CASE.—The P.T. on the straight line outside of the given curve.

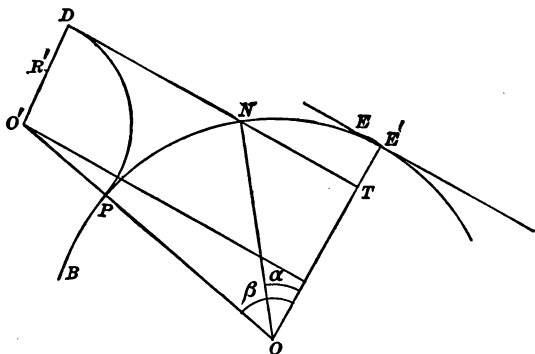


FIG. 47.

In Fig. 47, α is found as before, and β is to be determined. Similarly as in the preceding case, we have

$$R \cos \alpha = OT,$$

and $(R + R') \cos \beta + R' = OT,$

or, $R \cos \alpha = (R + R') \cos \beta + R',$

whence $\cos \beta = \frac{R \cos \alpha - R'}{R + R'} \quad (78)$

and $\beta - \alpha =$ the angle PON , with which P may be located, and the curve PD set out.

89. Given a tangent TT' , and a curve TV , it is required to connect these by a curve VT' of known radius forming a **Y** at some point V . The tangent points T' , V , and the angles α and α' are to be determined.

In Fig. 48, suppose PV drawn from the middle of TT' tangent to the curves at V . This construction makes PT , PV , and PT' equal. Connect the centers O and O' . Now since the supplementary angles TPV and $T'PV$ are bisected respectively by OP and $O'P$ the angle OPO' is a right angle and PV is therefore a mean proportional between the radii R and R' .

Or denoting PV by x and the angles at O and O' by α and α'

$$x = \sqrt{RR'} = PV = PT = PT'; \quad (79)$$

hence

$$\tan \frac{1}{2} \alpha = \frac{x}{R} = \sqrt{\frac{R'}{R}}, \quad (80)$$

and

$$\alpha' = 180 - \alpha.$$

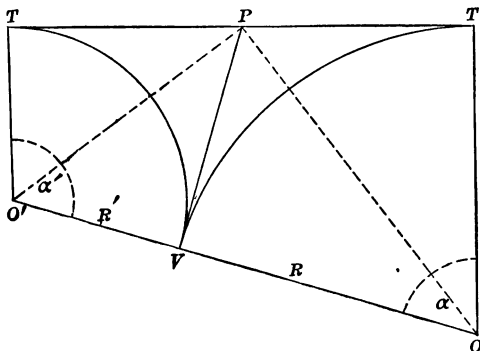


FIG. 48.

90. Given a curve TT' located, and the radii of two other curves, it is required to connect the system forming a Y, as indicated in figures 49 and 50.

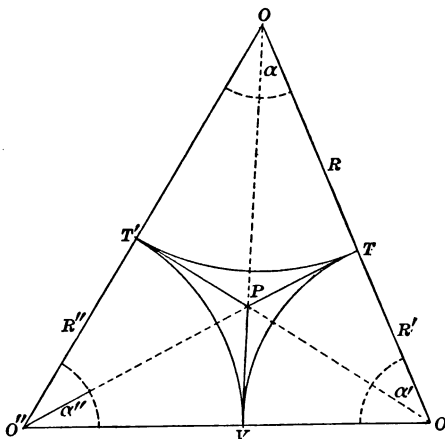


FIG. 49.

FIRST CASE. — The curves being convex to each other, as in figure 49. Connect the centers of the curves O, O', O'' , thus

forming a triangle in which the three sides are known, and compute the angles and thence the common tangent distance. Practically find one of the central angles as α , then

$$\text{Tangent distance} = x = R \tan \frac{1}{2} \alpha = PT = PT' = PV; \quad (81)$$

$$\left. \begin{aligned} \tan \frac{1}{2} \alpha' &= \frac{x}{R'} = \frac{PT}{R'} \\ \tan \frac{1}{2} \alpha'' &= \frac{x}{R''} \end{aligned} \right\} \quad (82)$$

and

whence the limiting points of the curves are determined.

EXAMPLE. — Given TT' , a $3^\circ 20'$ curve, and TV , a $4^\circ 40'$ curve, it is required to connect them by VT' a 6° curve. Compute the central angle and the common tangent distance.

SECOND CASE. — The curves being convex in the same general direction. Fig. 50.

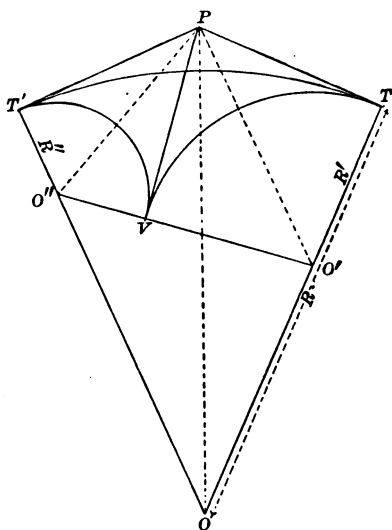


FIG. 50.

$$\begin{aligned} OT &= R \\ O'T &= R' \\ O''T' &= R'' \end{aligned}$$

Connect the centers $O O' O''$ of the curves thus forming a triangle and compute the central angles and common tangent distance as in the first case.

The student may show, by construction, how to locate P , the intersecting point of the tangents.

EXAMPLE. — Given TT' a $1^\circ 20'$ curve, and TV a 7° curve, to connect by an $8^\circ 30'$ curve VT' . Compute the central angle and the common tangent distance.

91. To lay out a track of a given length, having circular ends connected by two tangents of known directions, and of given distance apart at either end.

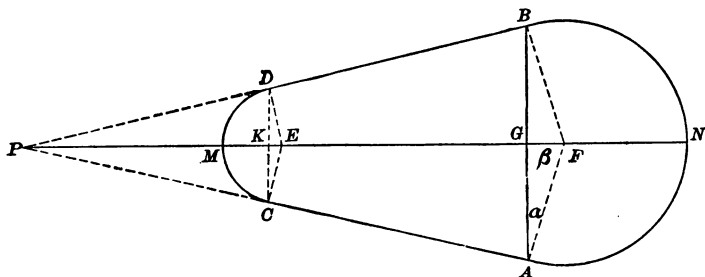


FIG. 51.

In the figure denote the line AB by b , the known angles FAG and AFG , as found from the direction of the tangents, by α and β respectively. Call DB , y ; DP , x ; DC , c ; BF , R ; and DE , r .

Then the distance round, or length of track,

$$d = 2 \left[\frac{\pi R}{180} (180 - \beta) + y + \frac{\pi \beta r}{180} \right]. \quad (83)$$

Now,

$$R = \frac{b}{2} \sec \alpha,$$

$$r = \frac{c}{2} \sec \alpha,$$

$$x = \frac{c}{2} \operatorname{cosec} \alpha,$$

$$y + x = \frac{b}{2} \operatorname{cosec} \alpha,$$

$$y = \left(\frac{b}{2} - \frac{c}{2} \right) \operatorname{cosec} \alpha.$$

Substituting in (83), we obtain

$$d = 2 \left[\frac{\pi}{180} (180 - \beta) \frac{b}{2} \sec \alpha + \left(\frac{b}{2} - \frac{c}{2} \right) \operatorname{cosec} \alpha + \frac{\pi \beta}{180} \cdot \frac{c}{2} \sec \alpha \right], \quad (84)$$

in which c is the only unknown quantity.

EXAMPLE. — If $AB = 500$, the distance round $\frac{1}{2}$ mile and $\beta = 80^\circ$.

$$\text{Then, } 2640 = 2 \left[\frac{5}{9} \pi \cdot 250 \sec 10^\circ + \left(250 - \frac{c}{2} \right) \operatorname{cosec} 10^\circ + \frac{4}{9} \pi \cdot \frac{c}{2} \sec 10^\circ \right].$$

From which c may be found, thence the arcs DMC , ANB , and the tangent DB .

92. Given two curves united by a tangent, to substitute for the tangent a simple curve of known radius, compounded with the others.

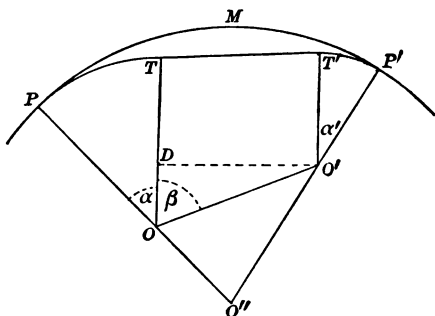


FIG. 52.

Denote by R the radius OT ,

“ R' “ $O'T'$,

“ R'' “ $O'P = O'P'$,

“ d the distance between tangent points TT' ,

“ α the angle TOP ,

“ β “ DOO' .

Draw $O'D$ perpendicular to OT .

Then
$$\tan \beta = \frac{d}{R - R'},$$

and
$$OO' = (R - R') \sec \beta.$$

Now in the triangle $OO'O'$, the sides being known, find the angle O , hence the angle α , and thereby locate the point P . In a similar manner the point P' may be located.

Can a radius as short as $\frac{1}{2}(R + R' + OO')$ be employed?

If $R = R'$, show that

$$\sin \alpha = \frac{d}{2(R'' - R)}.$$

EXAMPLE. — Given two curves, TP and $T'P'$, of $4^{\circ} 40'$ and $5^{\circ} 50'$ respectively, connected by a tangent of 500 feet in length, to replace by a simple curve of $1^{\circ} 30'$.

93. To locate a tangent to a given curve from a fixed point without.

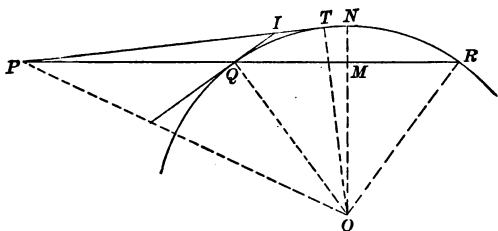


FIG. 53.

Let QTR be the given curve and P the point. If the ground is clear and the point not over 200 feet distant, proceed as follows :

Measure in the direction of the curve to Q , and onward to R . Then by geometry

$$PT = \sqrt{PR \times PQ}. \quad (85)$$

With one end of a tape pivoted at P , observe where the length PT cuts the curve. This will be the point of tangency. If the distance is greater, measure as before to Q , and observe the angle which the chord QR makes with the tangent QI , at Q . Thus the central angle becomes known, OM and QM may be calculated, and thence

$$\tan OPM = \frac{OM}{PM}.$$

But

$$\tan OPT = \frac{R}{PT},$$

and the angle

$$MPT = OPT - OPM.$$

$PO = PN$, and turn the telescope in the direction of OR , the prolongation of LN , by deflecting 60° from the direction of PO . NO is evidently equal to $PO = PN$.

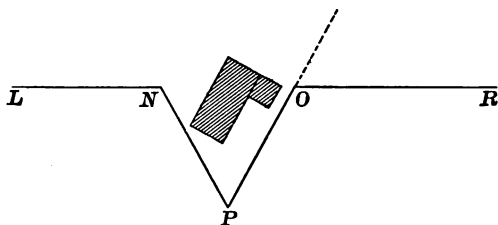


FIG. 57.

THIRD METHOD. — Erect a perpendicular, NK , of sufficient length that a line passing through K parallel to LN will clear



FIG. 58.

the obstacle; run KM ; lay off $MO = NK$, and a right angle turned from MO will indicate the direction of LN , or its prolongation OR .

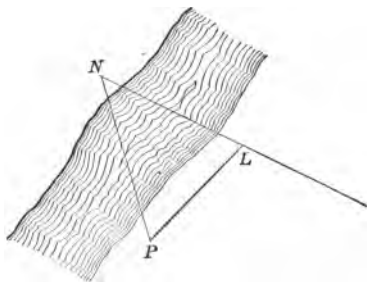


FIG. 59.

OTHERWISE, if a stream or pond, measure a base line LP , and the angles at L and P ; then, by the law of sines,

$$LN = \frac{LP \times \sin P}{\sin (L + P)}. \quad (88)$$

97. Given a railroad track on a curve to find the radius.

On the curved track XY take any point L , and measure a straight line LN , and from its middle point Q , measure the perpendicular QM to the track. Then denoting the radius MO by R , the chord LN by $2c$, and the middle ordinate MQ by m , we have, from a well-known proposition in Geometry,

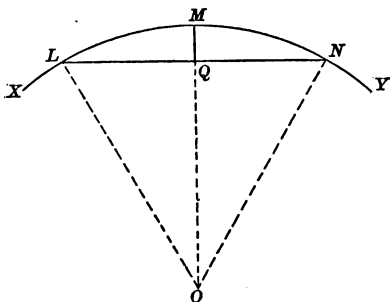


FIG. 60

$$m : c = c : 2R - m,$$

whence

$$R = \frac{c^2 + m^2}{2m}. \quad (89)$$

98. To locate a curve parallel to a given curve and at a definite distance from it.

Let $BCDE$ be the given curve, $B'B''$, $E'E''$, etc., points on radial lines through B , E , etc. To locate $B'E'$ parallel, and at a given distance from the first, use the same deflection angle and find the length of chord $E'D'$ from the proportion

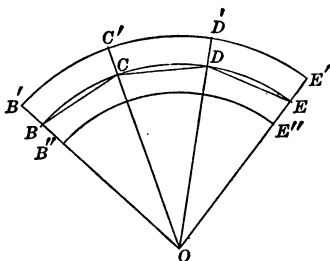


FIG. 61.

$$R : ED = R + EE' : E'D',$$

or, denoting

$$R + EE' \text{ by } R',$$

a well-known formula will give

$$E'D' = 2R' \sin EOD; \quad (90)$$

and similarly for the curve $B''E''$.

EXAMPLE. — Given BE , a 4° curve of three stations, to find the length of chord required to run in the curve $B'E'$ 60 feet distant.

99. To connect two parallel tangents by a reversed curve.

FIRST CASE. — Given the length of the straight line connecting the tangent points, and the perpendicular distance between the tangents, to find one of the equal radii which shall unite the tangents by a reversed curve.

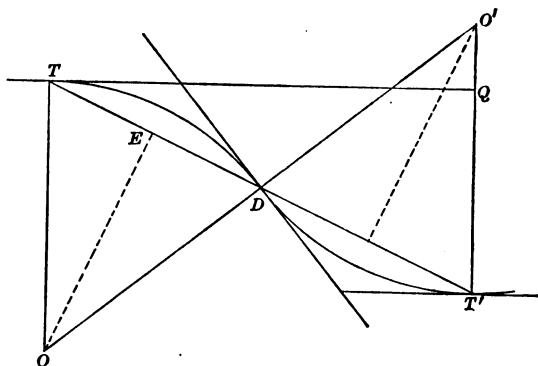


FIG. 62.

Denote $OD = DO'$ by R .

“ TT' by c .

“ $QT' = \text{perp. dist.}$ by d .

Draw OE to the middle of TD , then the triangles TOE and TQT' are similar, and the homologous sides give the proportion.

$$R : \frac{c}{4} = c : d,$$

or

$$R = \frac{c^2}{4d}. \quad (91)$$

The student may show, what is assumed in the foregoing, namely, that the point of reversed curvature D , is at the middle of TT' .

SECOND CASE. — The radii unequal, the same lines $TT' = c$, and $QT' = d$ given as before, and the length of one of the radii $OT = R$.

The student may find the unequal chord lengths DT and DT' , and show that the radius $O'T' = R'$ is equal to the product of DT and DT' divided by $2 QT'$, or denoting DT by c' and DT' by c'' , show that

$$R' = \frac{c'c''}{2d}. \quad (92)$$

Again, since

$$\frac{R}{R'} = \frac{c'}{c - c'},$$

and

$$c' = \frac{2dR}{c},$$

$$R' = \frac{c^2}{2d} - R. \quad (93)$$

Given a 3° curve AB , a straight line TT' intersecting it at T , making an angle of $40^\circ 54'$ with the tangent TN ; it is required to find the reversing point P whence an 8° curve may be run terminating in the given straight line TT' .

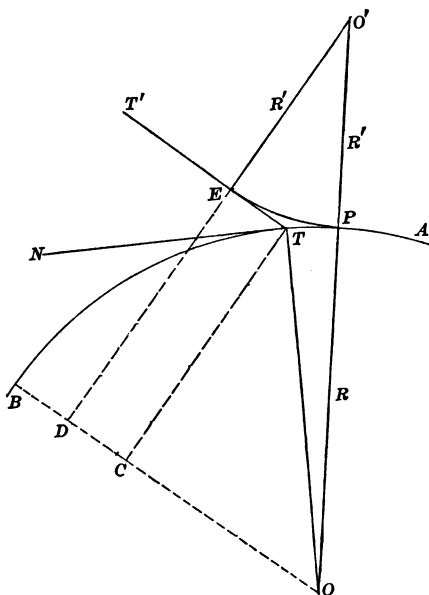


FIG. 63.

Let E indicate the P. T. of the required curve, and draw TC and ED perpendicular, and OB parallel to the given line TT' . Now R and R' are known, the angle $CTO = NTT' = 40^\circ 54'$ whence the angle COT and side $CT = ED$ can be found, hence the angles TOP and O' and the point P determined.

CHAPTER VI.

CONSTRUCTION.

A. GENERAL DIRECTIONS, DEFINITIONS AND PROBLEMS.

100. The position of the center line of the road being finally determined upon; its place indicated by stakes, their elevations taken, the profile made, and grades established, the next thing in order is to build the road. The work must be carefully set out; for example, stakes must be set for excavations and embankments, and for culverts, trestles, etc. The precise location and elevation of bridges and tunnels, if any, must be marked out; the amount of cutting and filling necessary to reduce the inequalities of the ground to conform to the grades must be ascertained; the kind, quality, and quantity of materials to be used in the construction, their most economic transportation, where, when, and how to be delivered. These and innumerable other problems and questions, present themselves to the engineer during the progress of the work, for solution or answer.

To proceed advantageously with this work, especially if the line is of considerable length, a re-organization of the engineer department is usually affected, the chief engineer having now division and resident engineers to assist him.

The chief, as before, has charge of the work, gives general directions, passes upon bids, estimates, etc., and decides numerous questionable matters referred to him by the division engineer.

A division engineer is placed in charge of several miles of the line in which there are a number of residencies, and to him the resident engineers report. From these reports monthly estimates are made, and forwarded to the chief for examination and approval.

A resident engineer has charge of the construction of a few miles of the road, and it is his duty to personally superintend it. With his assistant or rodman, he will show grade, or line, perform the necessary measurements and computations for the monthly estimates, and make the required report to his superior officer.

101. A cross-section is a vertical section taken at right angles to the vertical plane which embraces the center line; its extreme limits to the right and left depend upon the width of the road-bed, the transverse slope of ground, the side slope of cut or fill, and the cut at the center. The difference in the elevations of the surface and grade at the center gives the cut at that point.

A cross-section should be taken at every regular station, and at every other point where the surface of the ground changes its slope perceptibly, whether at the center or near the place of the side stakes, so that data may be had to calculate closely the amount of material removed.

102. A grade point, or a point where the natural surface of the ground intersects the grade, is neither in cut nor fill; such a point is discovered by setting the target of a leveling rod equal to the difference between the height of instrument and elevation of grade, and having the rod moved around until a place is found where the target is equal in height to the line of sight. A stake marked 0,0, should be set at such a point, and its position noted in the cross-section book.

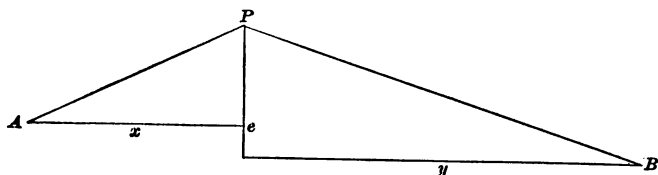


FIG. 64.

103. Given the elevations of two points A and B, their distance apart, and the gradients, to find some point P, where the grades will meet.

Denote the horizontal distance of AP by x .

" " " PB " y .

" " " AB " d .

" gradient of AP by a .

" " PB " b .

" difference in elevation of A and B by e .

Then $x + y = d$, and $ax + by = e$, using the plus sign when the grade rises from P to B and the minus sign when the grade falls from P to B .

From the last two equations the values of x and y may be found, and the point P thereby located.

For example, suppose the gradient from A rises .5 foot per station and from P to B it falls .8 foot per station, the difference in elevation of A and B 2.8 feet, B being lower than A , and from A to B there are 10 stations.

Then

$$x + y = 10$$

$$\frac{1}{2}x + \frac{4}{5}y = 2.8,$$

whence

$$x = 4 \text{ and } y = 6.$$

Showing the point P to be four stations from A .

104. To find where a grade will pass from cut to fill or vice versa, the slope of the ground being uniform between stations.

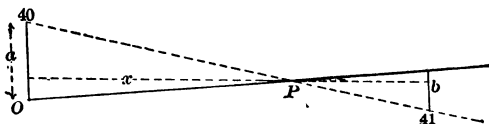


FIG. 65.

1. Given the cut at station 40 equal to a , and the fill at 41 equal to b , find the grade point P . By similar triangles we have

$$a : x = b : 100 - x,$$

whence

$$x = \frac{100a}{a + b}. \quad (94)$$

If $a = 10$, and $b = 4$, x will be 71.4'.

2. Given cut at station 40 equal to a , rise of grade per station equal to m , and the slope of ground n to 1, find x , the distance to the grade point P .

$$\frac{m}{100}x + \frac{x}{n} = a,$$

whence
$$x = \frac{100na}{mn + 100}. \quad (95)$$

If $a=8$, slope of ground 10 to 1, and rise of grade per station 1.5', x will = 69.6'.

3. Find an expression for x , assuming the grade falls b ft. per station; the other conditions as in example 2.

105. Vertical Curves. Where two grades meet an angle is formed, and it is necessary to lessen the grade at the point of meeting, and for a short distance both ways therefrom, say from 100' to 200'.

FIRST METHOD.—A very practical and generally sufficiently accurate method to round off two grades is to make, on profile paper, a drawing of the grades to a large scale, say 2 feet or $2\frac{1}{2}$ feet to the inch vertically, and 40 or 50 feet to the inch horizontally; then fit a proper curve to them and scale off every 25' or 50' the distances to points therein.

SECOND METHOD.—Let MN and NO represent the grades to be rounded off. Measure equal distances in both directions

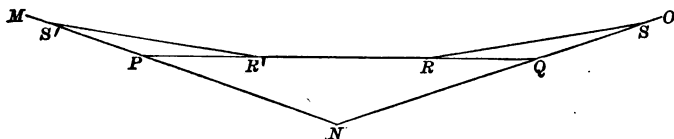


FIG. 66.

from the point where the grades meet, as $NP = NQ$ equal say 150' or 200', and connect the points P and Q by a straight line. If the angle of intersection of the grades is very small, this line PQ , with a little rounding up at its extremities, may be taken for the grade required. Then the ground must be cut away or filled up to it, depending upon the work whether it is in cut or fill. By repeating the operation, that is to say

connecting R and S , points 100' each way from Q , and also R' and S' , equidistant from P , a nearer approximation to a curve will be attained, and in surfacing the road any slight angularities at the points of meeting, as at R and S , can be removed.

106. Difference in elevation of the rails on curves. The centrifugal force F , of a car moving in a curved track of radius R , and velocity v , is given by the well-known general formula in Mechanics $F = \frac{v^2}{R}$. To oppose this force the outside rail on curves is set higher and the inside rail lower than the grade of the center line.

The problem is to find the difference in elevation of the rails, so that as a car moves round a curve on the inclined plane thus formed by the unequal elevation of the track, the action of gravity to draw it down the plane will just equal the centrifugal force. We have given R , v , and the distance between the centers of the rails d , to find the difference in height h , the linear dimensions being in feet, and v in feet per second. The action of gravity upon a body lying on an inclined plane varies with the sine of the angle of the plane. The component of gravity, therefore, that opposes the centrifugal force $= 32\frac{1}{2} \sin \alpha$, α being the angle of the plane.

Substituting the value of $\sin \alpha$, and equating the forces we obtain

$$\frac{v^2}{R} = \frac{193}{6} \frac{h}{d},$$

$$\text{whence} \quad h = \frac{6dv^2}{193R}. \quad (96)$$

If instead of $v =$ feet per second, we write $V =$ miles per hour $= \frac{3600}{5280} v$ there results

$$h = \left(\frac{22}{15}\right)^2 \frac{6dV^2}{193R} = \frac{.06687dV^2}{R}. \quad (97)$$

Substituting 4'.9 for d , which is about its proper value for the standard gauge of 4' 8½'', and writing for the radius its equivalent in terms of the degree of curve, there results

$$h = .00655 V^2 \sin \frac{1}{2} D. \quad (98)$$

Which is the formula employed to calculate the following table :—

V	DEGREE OF CURVE.								
	1°	2°	3°	4°	5°	6°	7°	8°	10°
20	.02	.05	.07	.09	.11	.14	.16	.18	.23
30	.05	.10	.15	.21	.26	.31	.36	.41	.51
40	.09	.18	.27	.37	.46	.55	.64	.73	.91
50	.14	.29	.43	.57	.71	.87	1.00		
60	.21	.41	.62	.82	1.03	1.23			

In calculating the height in any given case, the velocity assumed should be that of the train of the highest speed which will regularly pass around the curve, since if the centrifugal force developed be not thus counteracted, an accident might occur from the excessive pressure of the flanges of the wheels against the outside rail. On the other hand, the flanges of wheels on cars running at a lower rate of speed around the same curve would be forced by gravity against the inside rail. The effect of this would be to wear off the inside surface of that rail, but it would not jeopardize life and property to the extent of the former pressure, if the outside rail were not properly elevated; and as it is obviously impracticable to guard against both, the value of V indicated above should be used. It is better, however, all things considered, to reduce the speed of fast trains when running round sharp curves than to elevate the rail unduly.

With regard to the elevation of the outer rail, the practice among engineers is not precisely uniform. Some think $\frac{1}{2}$ inch elevation per degree sufficient for speeds up to 50 miles per hour. Others give $\frac{3}{4}$ of an inch per degree up to 5°, and $\frac{1}{2}$ inch per degree thence up to 10°.

Another rule is to elevate the outer rail

1 inch	for a 1 degree curve,
2 inches	" 2 " "
3 "	" 3 " "
3½ "	" 4 " "
4 "	" 5 " "
4½ "	" 6 " "

and slacken speed for greater curvature rather than elevate the rail above the last height. It is evidently unwise to lay down a specific rule, based upon the degree of curve simply, since the location of the curve will in practice enter the problem as a factor. When the curve is in a low place approached by a heavy grade, more elevation should be given than when the curve is on a summit, or at or near an important station, or wherever the conditions favor an easy approach.

The table shows the theoretical requirements, and the engineer must exercise good judgment in its application as in all things else.

The difference in elevation of the rails on a curve, if transition curves are not used, is the same from the P.C. to the P.T. From each of these points it is diminished gradually along the tangent until it becomes zero. The range for this distance is from 50 to 200 feet, depending upon the curvature. For a 3° or 4° curve the distance should be about 100 feet; for an 8° or 10° curve about 200 feet. For a compound curve the average of the elevations due to its branches gives the proper difference in height at the P.C.C.

It is the practice on most roads to increase the gauge on curves varying from ¼" to ½".

107. Inasmuch as it requires more force on a curved track than on a tangent to overcome the resistance of motion, it is customary and proper to make the grade somewhat less on curves than on tangents. This is called **easing, lessening, or reducing grades on curves**. The rules adopted are based upon the assumption that the resistance increases with the curvature; that is, the resistance offered by a curve of 2° is twice that of a 1° curve.

On the Central Pacific Railroad, in the Sierra Nevada Mountains, grades were lessened for curvature from 2 to $2\frac{1}{2}$ feet per mile per degree, on curves from 2° up. Or on an 8° curve, the grade was made from 16 to 20 feet per mile less than on the tangents. On the location through Weber Cañon, on the Union Pacific Railroad, grades were reduced $\frac{3}{100}$ per degree per hundred feet; that is, if a maximum grade on tangent was one foot per hundred feet on an 8° curve, it was made $1 - \frac{3}{100} \times 8 = \frac{76}{100}$ of a foot, or a reduction of about 13 feet per mile. Other roads use $\frac{5}{100}$ per degree per hundred feet, which, for an 8° curve, makes a reduction of about 21 feet per mile.

B. SETTING SLOPE STAKES.

108. The nature of the ground to be excavated being known, or assumed to be known, the ratio of the side slopes — base to height — may be fixed upon; the depth of cut at center being computed, and the width of road-bed decided, sufficient data are furnished to set the *slope stakes*, which indicate the limit of cut or fill.

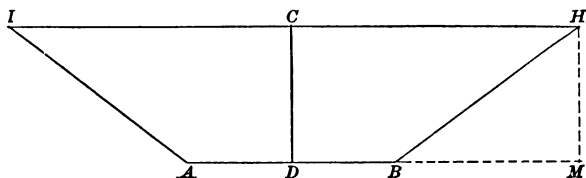


FIG. 67.

Suppose the ground is level transversely, and that $ABHI$ represents the cross-section.

Denote the width of road-bed AB by w ,
 “ “ cut CD , at center, “ c ,
 “ CI or CH , the distance from center
 to place of slope stake, *distance out*, “ d ,
 and the ratio of base BM to height MH “ $r : s$.

Then
$$d = \frac{w}{2} + \frac{r}{s}c, \quad (99)$$

ordinarily for clay cuts $r:s=3:2$,

$$\text{or,} \quad d = \frac{w}{2} + \frac{3}{2}c. \quad (100)$$

If the ground slopes transversely, let $ABFCE$ represent the section. The line EF may be straight, or it may be broken at C . The distance out on the right-hand side will evidently be greater than that for the level section, while that on the left side will be less. In all cases, if the inclination CF of the ground be ascertained, the distance out to F can be readily calculated as follows:—

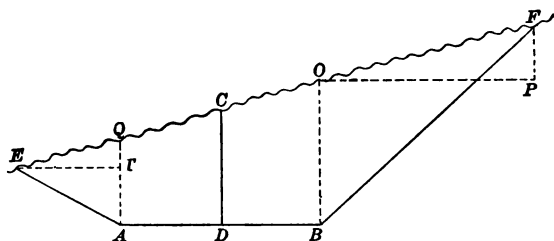


FIG. 68.

Obtain directly from the given slope of ground the depth of cut at foot of slope, as at B .

Denote this cut, the line	BO by c' ,
“ “	OP “ δ ,
“ “	PF “ x ,
“ the slope of ground, horizontal to vertical “	$m:n$,
“ “ side slopes as before	“ $r:s$.

Then $\frac{n}{m} \delta = x$,

and $\frac{s}{r} \delta = c' + x$,

or, $\frac{n}{m} \delta = \frac{s}{r} \delta - c'$;

whence, $\delta = \frac{mrc'}{ms - nr}$, (101)

and $d = \frac{w}{2} + \frac{mrc'}{ms - nr}$. (102)

or assuming and inserting values as in the preceding, namely $r : s = 3 : 2$, there results,

$$d = \frac{w}{2} + \frac{3mc'}{2m - 3n}. \quad (103)$$

Measure out the distance d , sight a rod on the point thus reached, and see if the observed and computed heights agree quite closely, say within a tenth of a foot. If they do not, probably the ground does not slope uniformly as was assumed, and the work must be revised.

A stake must be driven at the point F , marked with figures indicating the depth of cut there, preceded by a C for cut, facing the center line of the road, and a record made in the cross section book of the *distance out* and *depth* of side cut. In case of a fill, the letter F should be substituted for C . Some engineers prefer the signs $+$ and $-$ for cut and fill respectively, but the letters are preferable.

Evidently the same general formula (102) for **upper side stake in cut**, will answer for the **lower side stake in fill**, and if the ratio of side slopes is the same in both, $3 : 2$, the particular formula (103) may be used. On account of drainage, the width of road-bed must be from 4 to 6 feet wider in cut than in fill.

REMARK.—The ratio for ordinary earths is $\frac{3}{2}$ to 1; for solid rock, $\frac{1}{4}$ to 1; and for loose rock, and sand in embankment, 1 to 1.

For **distance out, lower side stake in cut**, we use the following notation :

Denote	ET by δ' .
"	AQ " c'' ,
"	QT " x' ,
"	distance out " d' .

And the other notation as above.

Then $\frac{n}{m} \delta' = x,$

and $\frac{s}{r} \delta' = c'' - x,$



CONSTRUCTION.

$$\frac{h}{m} \delta' = c'' - \frac{s}{r} \delta';$$

whence,

$$\delta' = \frac{mrc''}{ms + nr}, \quad (104)$$

and

$$d' = \frac{w}{2} + \frac{mrc''}{ms + nr}. \quad (105)$$

which formula will answer for **distance out, to down-hill stake in cut, or up-hill stake in fill**, and may be modified as (102) when the ratio of the side slopes is determined. If $r:s = 2:1$,

$$d = \frac{2mc''}{m + 2n}. \quad (106)$$

EXAMPLES.

1. Given width of road bed 20 feet, depth of center cut 13', side slopes $r:s = 3:2$; slope of ground $m:n = 10:1$. Find d .

$$c' = 13' + 1' = 14',$$

and substituting in (103)

$$d = 10 + \frac{3 \times 10 \times 14}{2 \times 10 - 3} = 34'.7. \quad \text{Ans.}$$

The result shows that the rod reading at the side stake, if the ground slopes uniformly from center out 10:1, should be 3'.47 less than that at the center.

2. Find in Example 1 the *distance out* to lower side stake, and depth of side cut. State what the rod reading should be.

3. Given, width of road-bed, 26 feet; side slopes, $\frac{1}{4}$ to 1; surface slope, 14 to 1; center cut, 16 feet. Find the distance out both ways from center, and the rod readings.

109. When the surface of the ground cuts the road-bed, part of the work is in excavation and part in embankment; this is called **side-hill work**.

In this case, the upper side can evidently be determined as before. For the lower side, a formula can be readily deduced.

The distance DG , and hence the fill AO , can be determined from the slope of the ground. It remains to find the distance OQ , which shows the position of E .

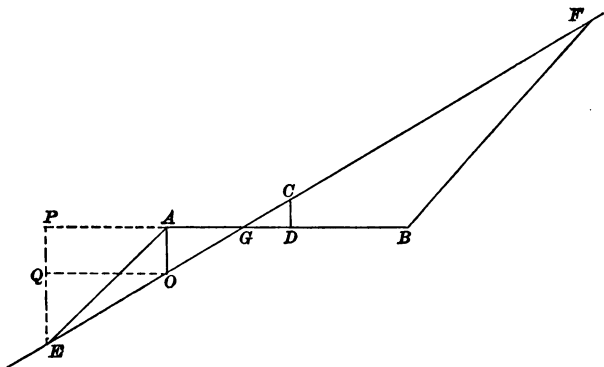


FIG. 69.

Denote AO by c'' ,
 " OQ " δ' ,
 " QE " x ,

and the other notation as before.

Then
$$\frac{n}{m} \delta' = x,$$

and
$$\frac{s}{r} \delta' = c'' + x;$$

whence
$$\delta' = \frac{mrc''}{ms - nr}. \quad (107)$$

which, added to half width of road-bed, gives the distance out, and it will be perceived that (107) is analogous to (101), as might have been inferred.

EXAMPLES.

1. Given center cut 2 feet, slope of ground 4 to 1, slope of sides 3:2, width of road-bed 20 feet. Find distance out both ways and the corresponding heights. Locate also the grade point.

2. The problem shown in figure 70 may be solved like the preceding. For from the slopes the value of c'' can be found,

ratio of side slopes, and assumed rise from center, calculate the distance out. Observe the rod on this point and if it agrees within the prescribed limits, say a tenth of a foot, drive a stake there; if not, estimate again, and profiting by the knowledge obtained during the preceding effort, one or two more trials should be sufficient, and less time consumed than by the formula.

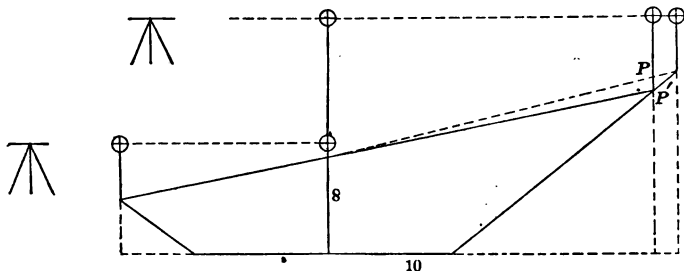


FIG. 71.

For example suppose the road bed 20 feet; center cut 8 feet; side slopes 3 to 2, and we estimate the rise from the center stake to the place where the side stake should be set equal to 4 feet. Then the distance out should be $10 + \frac{3}{2}(8 + 4) = 28$ feet, and if the rod reading at center was 7 feet, that at the side should be 3 feet. Now suppose the reading should be found only 2 feet, at 28 feet distance from the center. Such a result would show the ground to be higher at *P* than it was estimated, and therefore the position of the stake farther out.

We perceive that an additional distance of three halves of a foot will take up the rise of one foot, which is the difference between the estimated and observed rise, but since the ground *rises*, the rod reading at this distance, 29.5 feet, will be *less* than 2 feet, and therefore a little greater length must be taken. Try $d = 30'$ which gives a rise from road bed of $\frac{2}{3}(30 - 10) = 13.3'$, and a corresponding rod equal to $15' - 13.3' = 1.7'$. Measure out this distance, sight the rod and see if it does not agree within a tenth.

Proceeding in a similar manner to set the down-hill stake, we may estimate that the ground falls 2 feet from the center

to its place, making the distance out, 19 feet, and supposing the rod reading at center 2', that at 19' should be 4'. Suppose it is found to be 3.5'; this shows that the slope of the ground is not as great as it was estimated, and that the position of the stake is a little farther out. Now we perceive that three-fourths of a foot more horizontally will bring the side slope half a foot higher, which is the difference between the estimated and observed rod reading, but since the ground falls in the direction of the measurement, we do not require quite a half-foot rise, perhaps a tenth less; that is, instead of a reading of 3.5' feet, we should expect a reading of about 3.6'. For this we must go out $10 + \frac{3}{2} (8 + 2 - 3.6) = 19.6'$ Measure out this distance, observe the rod, and see if the agreement is not sufficiently close.

If the rod reading at 19' had been greater than four feet, it would show that the stake should not be as far as 19' from the center.

From the foregoing considerations respecting slope staking we can write the following

RULE.

In **excavation**, if the **observed rod reading** is $\left\{ \begin{array}{l} \text{less} \\ \text{greater} \end{array} \right\}$ than the **computed**, for the supposed site of stake, it indicates that the true position of the stake is farther $\left\{ \begin{array}{l} \text{out} \\ \text{in} \end{array} \right\}$.

In **embankment**, if the **observed rod reading** is $\left\{ \begin{array}{l} \text{less} \\ \text{greater} \end{array} \right\}$ than the **computed**, for the supposed site of stake, it indicates that the true position of the stake is farther $\left\{ \begin{array}{l} \text{in} \\ \text{out} \end{array} \right\}$.

Sta.	Elevations.	Grade.	Left.	Center.	Right.	Area.	C. Yds.	Remarks.
43	490.8	473.2	$\frac{+ 16.5}{25.5}$	+ 17.6	$\frac{+ 20.5}{29.5}$	650.5	3260	Width of road-bed, 18'. Grade rises 1' : 1 per station. Slopes, $\frac{3}{4}$: 1.
44	499.7	474.3	$\frac{+ 20.7}{29.7}$	+ 25.4	$\frac{+ 31.7}{40.7}$	1129		

112. The above table exhibits a form of recording the notes. The last two columns will be explained farther on. The first two columns are taken from the level notes; the third and fifth calculated from the elevations and adopted grade; and the fourth and sixth supplied on the field during the operation of setting slope stakes. The plus sign indicates a cut at station 43 of 17'.6, and that the right and left side stakes for that station are respectively 20'.5 and 16'.5 above the plane of the road bed. A minus sign correspondingly placed would indicate a fill. The denominators of the fractional expressions show how far these stakes are placed horizontally from the center. In general, the numerators of the fractions, found in the notes, exhibit the cuts or fills and the denominators the distances out.

If the surface of the ground transversely is such that it cannot be considered level, or as having a uniform slope to the side stake, the cross-section party must ascertain the inequalities and make record of them in the cross-section book.

113. In staking out the work allowance should be made for the change in volume of the material to be removed from excavation to embankment. If the nature of this material is earthy it will occupy less space in embankment than in excavation, and *vice versa* if rocky.

In regard to the *shrinkage*, however, much depends upon the condition as well as the composition of the material, and also the manner in which it is placed in the fill. If it is wet, or frozen, and simply shovelled or even dumped from scrapers a greater allowance should be made than if it is dry; or if the conditions be the same, and carts or wagons be used to transfer the material to a long, large fill, a less allowance should be made because the earth becomes solidified by the impact of the horses and loads. Moreover sandy soils will not shrink as much as those in which clay preponderates.

A fair average for the shrinkage is taken at one-tenth, $\frac{1}{10}$. That means that a fill which is to be 13.5 feet at grade must be made 15 feet high at first so as to allow for a settlement of 1.5 feet; or a fill finished at 10 feet will settle to one of 9 feet.

Rock, on the contrary, when broken increases in bulk; the increase depending upon the size of the pieces, being greater for small pieces than for large ones. A fair average increase may be taken at two-thirds, $\frac{2}{3}$, or 3 cubic yards of rock in cut will make 5 cubic yards in fill.

C. CALCULATING THE EARTH WORK.

114. From the cross section book we now obtain data sufficient to determine the quantity of earth to be removed, or the amount of cutting and filling.

The cross sections being parallel,* and having been taken sufficiently near each other that the lines connecting the corresponding points of any two consecutive cross-sections may be considered straight, and the sides of the figure planes, the prismoidal formula will give the exact quantity of earth in the solid. Or, if one end-section vanishes, being at grade as at the end of a cut or side hill work, there will be a wedge-shaped mass, or a pyramid formed; but since this formula is applicable to the wedge or pyramid, it may also be used in these cases to determine accurately the cubic contents. For illustration, conceive a prism, a wedge, and a pyramid having equal bases and altitudes; and let b denote the area of each base and h the common altitude.

Then the volume of the prism $= bh$,

or,
$$\frac{h}{6}(b + 4b + b).$$

The volume of the wedge $= \frac{1}{2}bh$,

or,
$$\frac{h}{6}\left(b + 4\frac{b}{2} + 0\right).$$

The volume of the pyramid $= \frac{1}{3}bh$,

or,
$$\frac{h}{6}\left(b + 4\frac{b}{4} + 0\right).$$

It will be perceived that b , $\frac{1}{2}b$, and $\frac{1}{4}b$, represent respectively the middle area of the prism, wedge, and pyramid, and therefore

* Except on curves where a correction is made. See Art. 118.

the volume of either of these solids, or any combination of them may be expressed by the following equation, known as the

PRISMOIDAL FORMULA.

$$V = \frac{h}{6} (A + 4M + B). \quad (108)$$

In which V denotes the volume,
 h “ “ distance between the ends,
 A and B “ “ end areas,
 and M “ “ area of section midway between the ends A and B .

REMARK. — The term *prismoid* usually suggests a body composed of the solids just named, that is, one having six plane surfaces of which only two are parallel, yet the “prismoidal formula” has a much wider application as was first shown by Ellwood Morris, C.E., in the Journal of the Franklin Institute in 1840. Trautwine says: * “It embraces all parallelopipeds, pyramids, prisms, cylinders, cones, wedges, etc., whether regular or irregular, right or oblique, together with their frustums, when cut by planes parallel to their bases; in a word, *any solid whatever, which has two parallel ends, connected together by either plane or by longitudinally unwarped surfaces.*”

Gillespie † shows that if the surface is warped, being “generated by a straight line resting on the two straight lines which join the extremities of the two end sections, and moving parallel to their planes or perpendicular to the axis of the road,” the prismoidal formula will give the correct result.

Or if the natural surface is generated by “a straight line which rests on the two end sections and moving on them in such a way as always to divide them *proportionally*” the formula is applicable.

If a ridge or hollow runs obliquely in one direction across the solid, from end to end, and its position determined with sufficient accuracy that the area of the mid-section as well as

* Trautwine on Excavations and Embankments, page 5.

† Gillespie, Roads and Railroads, pages 368-9.

that of the end may be computed, the prismoidal formula will still hold.

115. Sectional Areas. — To calculate the contents, we must compute the end areas and the area of the mid-section.

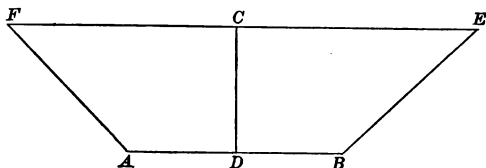


FIG. 72.

If the ground is level transversely, the area is evidently that of a trapezoid, having for bases the width of road-bed and the sum of the distances out, and for height the center cut.

Let d and d' denote distance out to right and left respectively, w the width of road-bed, and c the center cut.

$$\text{Then} \quad A = \frac{c}{2} (w + d + d'). \quad (109)$$

If the ground slopes uniformly from F to E through C , or if it has a uniform slope from either C' or C'' to E and F , CD being the center cut in the first case, and $C'D$ and $C''D$ center cuts in the last cases.

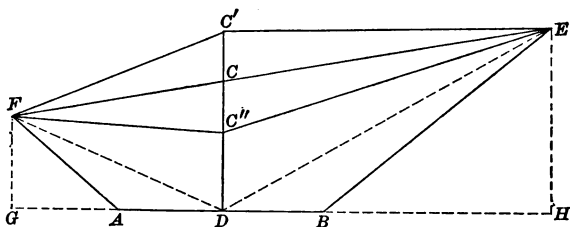


FIG. 73.

In either case two triangles may be formed, having for bases AD and DB , and FG and EH their respective heights, and two more triangles having for their common base the center

cut, and for heights the distances out. Calling h and h' the right and left side heights respectively, and using the notation above, the equation for the area may be written,

$$A = \frac{w}{4} (h + h') + \frac{c}{2} (d + d'). \quad (110)$$

The area of a section, as $ABECF$, Fig. 73, may be found without using the center cut, simply by subtracting from the area of the trapezoid $EFGH$ the area of the triangles BEH and AFG .

In case the ground is irregular, sufficient measurements should be made, so that the section may be divided up into triangles and trapezoids and its area thereby computed.

If the inequalities of the surface are numerous, it is generally sufficiently accurate to plot the section, average the inequalities by stretching a silk thread over them, scale off the necessary distances and heights, and compute the area by some of the preceding methods.

The middle area is found by first averaging the corresponding lines of the end sections, thereby obtaining the mid-section, and then in the usual manner, by formula (110) compute its area.

For example, if the center cuts at the ends A and B are 12' and 8' respectively,

and the corresponding distance

out to the right	34'	and 28',
and the distance out to the left	23.5'	" 17.5',
the side heights on the right	16'	" 12',
the side heights on the left	9'	" 5';

then the mid-section would have for center cut	10',
" " " distance out to right	31',
" " " " " left	20.5',
" " " side height to right	14',
" " " " " left	7',

and its area

$$= \frac{20}{4} (14 + 7) + \frac{10}{2} (31 + 20.5) = 362.5 \text{ sq. ft.}$$

116. The volume of the section referred to in the last paragraph, supposing the distance between the ends *A* and *B* to be 100 feet, and the width of road-bed 20 feet, will be computed as follows:—

Area of end *A*

$$= \frac{20}{4} (10 + 9) + \frac{12}{2} (34 + 23.5) = 470 \text{ sq. ft.}$$

Area of end *B*

$$= \frac{20}{4} (12 + 5) + \frac{8}{2} (28 + 17.5) = 267 \text{ sq. ft.}$$

Area of mid-section from last paragraph 362.5 sq. ft.

$$\therefore V = \frac{100}{6} (470 + 4 \times 362.5 + 267) = 30450 \text{ cu. ft.}$$

or, $30450 \div 27 = 1350 \text{ cu. yds.}$

The area of the cross-section at each station, when computed, is placed in the column of areas in the table on page 110, and the quantity of material between two cross-sections is placed, as shown, in the column of cubic yards.

The student may verify the areas and cubic yards in the table on page 110.

117. Instead of the prismoidal formula the method of averaging end-areas is very frequently employed. It consists simply in computing the areas of the ends of the sections, taking their arithmetical mean, and multiplying it by the length of the section. For example, suppose we take a mass of earth, level on top, center cut at one end 12', distance out each way 28', the road-bed being 20' and sides slopes $\frac{3}{2}$ to 1; the cut at the other end 14', distance out each way 31', the road-bed and side slope as before, and the distance between ends 100'; then, by averaging end areas, we obtain,

$$\text{Area first end} = (20 + 56) \frac{12}{6} = 456 \text{ sq. ft.}$$

$$\text{" second " } = (20 + 62) \frac{14}{2} = 574 \text{ " "}$$

$$\text{Average} = \frac{1030}{2} = 515 \text{ sq. ft.}$$

and the volume
$$= \frac{51500}{27} = 1907 \text{ cu. yds.}$$

By the prismoidal formula the correct volume is found to be 1904 cubic yards, but more labor is involved in the calculation.

Again, suppose the larger end section to remain as before, but the smaller to have only a 4' cut at center, the width of road-bed, side slopes, and length of section remaining unchanged, then we shall find by averaging end-areas $V = 1255 +$ cubic yards, but by the prismoidal formula the correct quantity is found to be 1163 cubic yards, so that in this case, by averaging end-areas, we get nearly 8 per cent. too much. Furthermore, if the smaller end-area vanishes, the surface being at grade there, the other dimensions and conditions the same as before, and the volume be computed by averaging end-areas and also by the prismoidal formula, we shall find an excess by the former method over the exact amount, computed by the latter, of more than 20 per cent. And in general it will be found that in a prismoid the greater the difference between the end-areas, the greater will be the departure from the true volume when the method of averaging end areas is used. The reason becomes obvious upon analyzing the figures found in the various cases. In the first and second, conceive a plane drawn parallel to the road-bed, and at a distance from it equal to the center cut at the smaller end. Also conceive two other planes extending throughout the section longitudinally and perpendicularly to the road-bed, one through each side stake at the smaller end-section.

These planes, with the surface of the ground, faces of the slopes, and the end sections divide the solid into a prism, a wedge, and two pyramids. In the first example the pyramids have *very small bases*, and therefore multiplying as we did, when averaging end-areas, by *one-half* the altitude instead of *one-third*, we increased the volume but little. In the second example, however, the bases of the pyramids are larger and the difference in the product between one-half and one-third is considerable.

In the third or last example, computed above, the mass may be divided into a wedge and two pyramids, the bases of the latter forming a still larger part of the area of the cross-section than in either of the other examples, an increased percentage in quantity obtained by end-areas over the correct result might be expected. While, therefore, in many cases quantities may be computed with sufficient accuracy by averaging end-areas, it will be perceived from the foregoing what conditions are favorable, and what unfavorable to an approximate result by this method, and that the engineer must exercise judgment in determining when to use the prismoidal formula instead. When the ground is very much broken and irregular, or in the case of *borrow pits*, the mass may be divided into small regular solids, by the level and tape, and their volumes determined by well-known rules of geometry.

When the precise quantities are required, as in piers, abutments, etc., the prismoidal formula should be used.

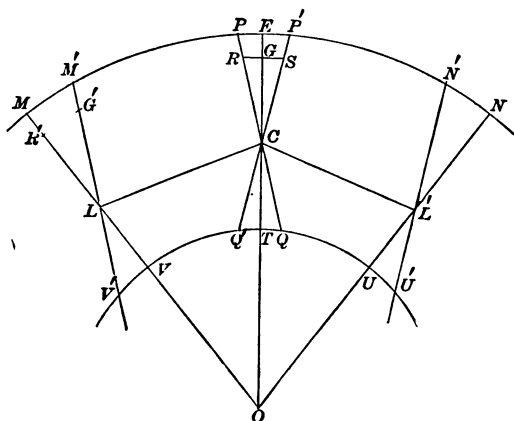


FIG. 74x.

118. Excavation on Curves.—In calculating the amount of excavation, we have thus far assumed that the cross-sections are perpendicular to a straight center line. The assumption is not theoretically correct on curves, though where the curve is

not very sharp, the error arising is generally slight. Moreover, when the method of averaging end areas is employed instead of the prismoidal formula, in computing quantities, any attempt to correct errors arising under the above assumption would be a needless refinement; still, where greater accuracy is demanded, and the prismoidal formula, therefore, freely used to obtain the volumes, it may be well not to ignore the effect of curvature, especially where the depth of cut is great, the radius small, and the transverse slope steep.

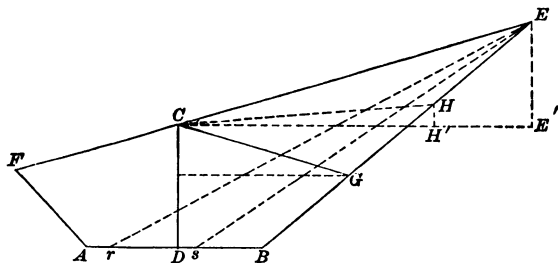


FIG. 74y.

Let Fig. 74x represent the horizontal projection of a portion of a road-bed in excavation on a curve, the center of which curve is at O , LCL' the center line, MEN the outside, and UTV the inside line of slope stakes. Now, in calculating the volume between the stations L and C , in the ordinary way we obtain the contents of the solid lying between the planes PCQ and MLV' , drawn at right angles to the straight line LC , thereby getting too much by the volumes of the wedge-shaped masses QTC and LVV' , and too little by the wedge-shaped masses $MM'L$ and PEC . If the distances out were equal, as shown in cross-section $ABGCF$ Fig. 74y, the overlapping on one side of the center line would counterbalance the gap on the other, and no correction would be necessary. In other cases, the overlap and gap may in general be represented by solids similar to QCQ' and PCP' respectively.

Suppose the case in question has a cross-section as $ABEF$ in 74y. We may proceed as follows, employing one of the theorems of Pappus, namely: If a plane area revolve round any axis in

its plane, the volume generated is equal to the area of the revolving figure multiplied by the length of the path described by its center of gravity.

Now, the center of gravity of a triangle is on a line joining the vertex with the middle of the base, and at two-thirds the distance from the vertex.

Let H indicate the middle of GE . Draw CE' horizontally, and project H and E on it at H' and E' respectively. Calling the distance out to E , d , and to F , d' , we perceive that

$$\frac{2}{3} CH' = \frac{2}{3} \cdot \frac{1}{2} (d - d') + d' = \frac{1}{3} (d + d')$$

or $\frac{1}{3}$ the sum of the distances out.

This added to the known radius, will give the radius R' , by which we may determine the distance traversed by the center of gravity of the plane in question.*

Let RS in (x) represent the required distance traversed,

$$RS = G'S - G'R = G'S - 100.$$

But

$$G'S = \frac{\pi R'D}{180}$$

$$\therefore RS = \frac{\pi R'D}{180} - 100.$$

Find then in the ordinary way, for straight center-line by the prismoidal formula, the volume of the mass between the stations L and C . From the mid-section find the area of the triangle CGE ,—by subtracting from the whole area, already computed, the part $ABGCF$,—which we may assume to be the plane area that generates the solid, or the wedge-shaped body sought.

Then the product of the length of RS , and the area of bGE will give C the correction required.

The correction must be added when the highest ground is on the convex side, and subtracted when the highest ground is on the concave side.

* Practically correct, but not *precisely* so theoretically.

EXAMPLE.

Given a 10° curve, or $R = 573.7$.

Cross section at A , ... $\frac{4}{18}$, $\frac{0}{14}$, $\frac{36}{80}$, and its area = 746

" " B , ... $\frac{2}{12}$, $\frac{0}{10}$, $\frac{20}{40}$, " " = 370

" " M , ... $\frac{3}{15}$, $\frac{0}{12}$, $\frac{28}{50}$, " " = 545

Vol. between the planes

PCQ and $M'LV' = \frac{6}{27} (746 + 2180 + 370) 100 = 2035$ cu. yds.

Area of triangle CGE in 74y = 335

$$CH' = \frac{1}{3} (15 + 50) = 21.67.$$

$$R' = 573.7 + 21.67 = 595.4.$$

$$RS = \frac{3.1416 \times 595.4 \times 10}{180} - 100 = 3.9$$

$$C = \frac{335 \times 3.9}{27} = 48 \text{ cu. yds.}$$

Therefore we obtain for the entire volume between MV and ET , $2035 + 48 = 2083$ cu. yds.

119. The following is Henck's method of making the correction at each station.* Adopting the notation employed in the preceding articles, namely,

c = the cut at the center,

d and d' , the greater and less distances out, respectively,

h and h' , the corresponding side heights,

w = the width of road bed.

Then the area of the triangle

$$CGE = \frac{1}{2} c (d - d') + \frac{1}{4} w (h - h').$$

The wedge-shaped mass horizontally projected at PCP' is considered a truncated prism, its edges PP' and RS , always short, are taken as straight lines, and at C the height of the solid vanishes.

$$\text{Now } PP' = 2 d \sin \frac{1}{2} D,$$

$$\text{and } RS = 2 d' \sin \frac{1}{2} D.$$

Then since the volume of the prism is equivalent to the product of the base, and one-third the sum of the edges, the

* Henck's Field Book, page 112.

formula for the volume and hence the correction sought is

$$C = [\frac{1}{2}c(d-d') + \frac{1}{4}w(h-h')] \frac{2}{3}(d+d') \sin \frac{1}{2}D \quad (111)$$

or, writing for $\sin \frac{1}{2}D$, its value in terms of the radius R ,

$$C = [\frac{1}{2}c(d-d') + \frac{1}{4}w(h-h')] \frac{100}{3R}(d+d'). \quad (112)$$

In side-hill work with such a cross-section as sBE , let b denote the base of the cut rB , Fig. 74 (y), then the height of the solid at E is the same as before, or $2d \sin \frac{1}{2}D$, the height at B is $w \sin \frac{1}{2}D$, and at any point between D and B as s , the distance of which from the center is $\frac{1}{2}w - b$, the height is $2(\frac{1}{2}w - b) \sin \frac{1}{2}D = (w - 2b) \sin \frac{1}{2}D$. Now calling b the base of the cutting, the area of the cross-section $sBE = \frac{1}{2}bh$ and hence the correction

$$= \frac{1}{2}bh \frac{1}{3}(2d + w - 2b) \sin \frac{1}{2}D,$$

$$\text{or} \quad C = \frac{1}{2}bh \frac{2}{3}(d + w - b) \sin \frac{1}{2}D. \quad (113)$$

When the excavation lies on both sides of the center line having a cross-section rBE , its area $= \frac{1}{2}bh$, the height of the solid at E and B will be as in the preceding paragraph respecting $2d \sin \frac{1}{2}D$ and $w \sin \frac{1}{2}D$; but at a point between A and D as at r , the distance of which from the center is $b - \frac{1}{2}w$, the height will be

$$2(b - \frac{1}{2}w) \sin \frac{1}{2}D = (2b - w) \sin \frac{1}{2}D.$$

This last height being on the opposite side of the center line from the others is considered negative in the product for the volume, hence the correction

$$= \frac{1}{2}bh \frac{1}{3}(2d + w - 2b + w) \sin \frac{1}{2}D;$$

$$\text{or} \quad C = \frac{1}{2}bh \frac{2}{3}(d + w - b) \sin \frac{1}{2}D, \quad (114)$$

precisely the same value of C given in (113).

Substituting for $\sin \frac{1}{2}D$ its value in terms of the radius we obtain

$$C = \frac{1}{2}bh \cdot \frac{100}{3R}(d + w - b). \quad (115)$$

Add or subtract as indicated above.

EXAMPLE.—Given the road bed 30 feet, the radius of the curve 800, the base of a side-hill cut 26, distance out to highest stake 60, and its corresponding height 28, all dimensions in feet, to find the correction.

$$C = \frac{1}{3} \times 26 \times 28 \times \frac{100}{2700} (60 + 30 - 26) = 971 \text{ cubic feet.}$$

120. Overhaul. — When contracting for the removal of material from excavation to embankment, it is sometimes stipulated that extra pay shall be had for the transportation of material through a distance greater than that specified, ranging usually from 300 to 500 feet. It may be necessary, therefore, to ascertain what is this extra distance known as overhaul, and on how much material the contractor is entitled to extra pay.

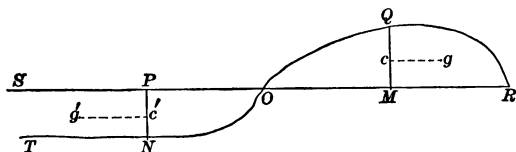


FIG. 75.

In the figure let the straight line $SPOR$ represent the grade line, and the curved line $NOQR$ the profile of a proposed railroad, where OQR is to be cut away and OTS filled up.

With a little computation of quantities, based upon the cross-section notes, and a few measurements and trials on the profile, the points *P* and *M* can be located, so that the cubic yards in *MOQ* and *PON* will be approximately equal -- near enough for practical purposes -- while the limit of free haul will be indicated by the distance *MP*.

Now, the contractor is entitled to additional compensation for the transport of all material from MQR to $NPST$, that is to say, if the center of gravity of MQR be at g and that of $NPST$ at g' , then the extra distance which this material is hauled $= gg' - PM$, or $cg + c'g'$. With a few trials, and a little figuring as before, a tolerably close approximation as to quantity and distance can be made. If greater accuracy is required, the center of gravity of each mass should be deter-

mined by the principles of Mechanics. This distance, usually reckoned in stations of 100 feet as the unit, multiplied by the quantity of material transported and by the price agreed upon for the overhaul, will give the amount due the contractor.

EXAMPLE. — If the limit of free haul be 400 feet, the distance between the centers of gravity of cut and fill be 1000 feet, the price one and a quarter cents per cubic yard per station of 100 feet, and the quantity of material, exceeding that of free haul, transported from cut to fill = 8000 cubic yards; then the extra pay

$$P = (10 - 4) 8000 \times \frac{1}{4} = \$600.$$

D. CULVERTS, BRIDGES, AND TUNNELS.

121. **Culverts** are used for the passage of water from one side of the road to the other under the track. If practicable, they should be constructed perpendicularly to the center line of the roadway. They are set out by driving stakes on the center line, and at the corners or angles indicating the limits of the foundations; and on each stake should be marked the depth required to be dug. In the note-book there should be made a sketch of the culvert, accompanied by a record of its dimensions, the amount of cutting at each stake, location of reference points, etc.

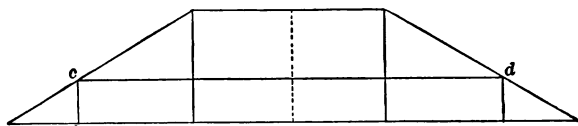


FIG. 76.

The length of a box culvert cd placed at right angles to the roadway may be found as follows : —

Let w = the width of the roadway,

“ a = the altitude of embankment,

“ $\frac{m}{n}$: 1, the ratio of side slopes,

and

h = height of culvert ;

then its length $l = w + 2 \frac{m}{n} (a - h).$ (116)

If $m : n = 3 : 2,$
 then $l = w + 3 (a - h).$ (117)

For a 20-foot fill, 16-foot roadway, and a culvert 6 feet high, slopes $\frac{3}{2} : 1,$

$$l = 16 + 3 (20 - 6) = 58 \text{ feet.}$$

Searles * says that in box culverts the span varies from 2 to 5 feet, the height in the clear from 2 to 6 feet, the thickness of walls from 3 to 4 feet, the thickness of cover from 12 to 18 inches, and its length at least 2 feet greater than the span. Furthermore, when the span required is more than 5 feet, and the embankment too high to warrant carrying the walls up to grade as an open culvert, an arch culvert should be used. The span varies from 6 to 20 feet; the arch is a semicircle, the thickness varying from 10 or 12 inches to 18 or 20 inches. The height of abutments to the springing lines varies from 2 to 10 feet, the thickness at the springing line from 3 to 5 feet, and at the base from 3 to 6 feet, the back of the abutment receiving the batter. The wing-walls stand at an angle to 30° with the axis of the culvert.

122. To set out bridge abutments when the **bridge is on a tangent**, proceed in a manner similar to that indicated for culverts, working from the axis of the roadway to locate the center line of the foundation for the main part of the abutment and its outside limits, and then the direction and extent of the pit for the wing-walls. All governing points to be referenced, care being taken that these stakes be placed where they will not likely be disturbed during construction.

When the **bridge is on a curve**, and especially if the span is considerable, the center of the abutment or pier should not be at the intersection of the axis of the bridge with either of these axis, but on a line LN , Fig. 77, called the bridge-chord.

* Field Engineering, page 209.

If the line curves, two transits may be employed to indicate by the intersection of their lines of sight the place for each bent.

The bents may be placed 12 or 15 feet apart, and for single track are usually composed of a sill, cap, two vertical posts, two batter posts, and two braces, running diagonally from sill to cap; all of 12×12 timber except the batter posts which may be 10×12 , and the braces 3 or 4 inches by 10 or 12. For double track roadway some modification of the preceding is necessary, more bracing is introduced, and for greater height than 28 or 30 feet some form of built-up post is employed, the posts being fastened together, thus forming a bent throughout the series, or the bents may be braced in pairs, making a pier, and the space between the piers spanned by a truss.

High wooden trestles are not as common in this country as formerly, having been largely superseded by iron structures.

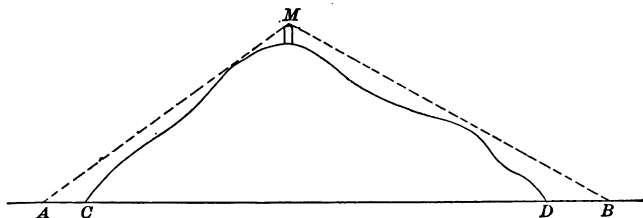


FIG. 78.

124. Tunnels. — Great care should be exercised in setting out tunnels. A first-rate instrument in good adjustment should be employed for observing direction of the line, and the best steel tape used for measuring the distance. A spring balance should be used with the tape so that a constant tension may be had, the measurements being made between plugs driven specially for this purpose, and the readings should be corrected for temperature.

If possible, some point should be selected in the line on the summit of the mountain as at *M*, whence an unobstructed view each way down the mountain may be obtained. Here a

monument should be erected, whence by numerous and careful observations made at different times, and using the mean result, stations *A* and *B* in the vicinity of the ends of the tunnel should be established precisely in a line which includes a point on the monument at *M*, from which the direction of the headings at *D* and *C* may be given.

It was discovered at the Musconetcong Tunnel that the best time during daylight to make an observation was just after sunrise. In summer it was quite impossible to do accurate work during the middle of the day. A round iron pole of one-half inch diameter, painted white and red alternately, answered well for a sight pole. The plummet lamp, however, sighted on a calm clear night gave the best results.

It is sometimes necessary to establish two or more stations on the mountain. In the alignment of the Hoosac Tunnel there were four permanent stations used. In such cases the difficulty of obtaining accurately the direction to drive the headings is considerably increased. In the Mont Cenis Tunnel an extended system of triangulation was resorted to in order to secure precision in the location of the axis of the tunnel.

In locating the Musconetcong Tunnel the first method above exhibited was employed with remarkable results ; the difference in the alignment of the east and west headings was only four hundredths of a foot.

If in addition to driving a tunnel from its ends, work is to be conducted from the foot of a shaft, carefully constructed apparatus must be provided, and extraordinary care observed in its manipulation to transfer accurately the direction of the line from the surface to the foot of the shaft. Various devices have been employed by engineers in solving this difficult problem. The principle thing is to suspend from two points *precisely* in the line, but on opposite sides of the shaft, at the surface, two plumb lines reaching to the place of the tunnel and obtaining thence the proper direction of the underground working.

In the Hoosac Tunnel the line was transferred 1000 feet down a shaft with such precision that when the heading, driven

over two miles from the west end, met the one produced over 2050 feet from the plumb lines, the error in the alignment was found to be only *nine-sixteenths of an inch*, and the heading driven from the shaft and plumb lines 1560 feet in the opposite direction met the corresponding one from the east with an error of only *five-sixteenths of an inch*.

125. In running the levels over the surface corresponding care must be exercised. The instrument should be kept in good adjustment, all the observations made on benches, and the readings taken to thousandths of a foot. The levels should be repeatedly tested so as to reduce the error to a minimum.

The difference of levels between points at the top and bottom of a shaft may be obtained by measuring with a rod the distance between lines made on a number of bolts, driven from 10 to 12 feet apart, in a vertical line down the shaft.

The grade of a tunnel should be at least sufficient for drainage, or about 0.15 of a foot per station, the least width in the clear for double track should be 28 feet, and the least height in the clear above the outside rail 16 feet. The center of the tunnel will of course be somewhat higher, depending upon the form of its cross-section.

Tunneling, like bridge building, has become an engineering specialty, and one who desires more knowledge on the subject should consult Drinker and Simms.

The information contained in the following extract from Mr. H. S. Drinker's paper on the Musconetcong Tunnel is as important to the engineer studying tunneling to-day as when it was written ; it is thought to be proper, therefore, to give it place here.*

The approach to the tunnel on the west begins on a 5° curve, the P.T. of which is about 800 feet from the entrance, and the tunnel itself located on a tangent throughout its length, the said tangent terminating in a curve, having its P.C. some 1850 feet beyond the east portal. The grade ran to a summit

* Read before the American Institute of Mining Engineers at New Haven, Conn., Feb. 25, 1875.

in the middle of the tunnel, the same being the summit for the road. It was reached by a rise of two-tenths (0.2) to the hundred feet on the west side, or 10.56 feet to the mile, falling on the east at fifteen-hundredths (0.15) to the hundred feet, or 7.92 feet to the mile.

To determine the line after its preliminary location, an observatory was erected on the summit of the mountain, about 12 feet high, with an eight-foot square base, battering on the four sides about $1\frac{1}{2}$ inches to the foot. Two solid stone foundations were also built on line, one on a hill about half a mile from the west entrance, the other on the grading, at the east end, and about half a mile from the eastern portal. As the observatory was located about midway over the tunnel, this gave, approximately, equidistant sights of about, say, a mile and a quarter each, at the farthest. This, however, was done after the tunnel had been started from points established on both sides by repeated and carefully checked runnings. The tower being subsequently built, two points were established, one each on the foundations, on either side, from the lines by which the work at either end had been so far run, and then assuming these end points as correct, by a series of repeated and careful trials, the center point on the tower, or permanent back-sight for both ends was determined by setting up, approximately, over it, and then reversing and sighting repeatedly, moving the instrument to and fro sideways, within a variable distance of about fifteen-hundredths (0.15) of a foot, in which the sights all came, and finally taking their mean. This was at first done, as soon as the observatory could be located and built, with sufficient accuracy to test the preliminary lines. Subsequently this center point was tested, and retested, and determined with extreme accuracy, by the mean of very many trials made both by sighting by day and by night, and in winter and summer. Different objects were used for sighting on in day work. Both the ordinary red and white round pole, also a flat 2×1 inch black pole, with a white center streak. This latter, from its shape, was found difficult to keep plumb, either when held or fastened. Also a pole of one-half inch round iron, painted white, was tried, and found to answer well,

better than either of the others. But far better and more accurate than any daylight back-sight, whether permanent or movable, was found the simple expedient of using plummet-lamps on clear calm nights. They worked admirably outside, a flame $\frac{3}{4}$ inch high, by $\frac{1}{2}$ inch in diameter, being distinctly seen in the long sights; and with a fine hair, the sights were found, finally, to repeatedly test within practically such exact limits (two or three hundredths), that, the point being once fixed, it was not subsequently found advisable to move it. Now, these three reference points being located, at the west end a center was set at the mouth of the slope, and from it another at the bottom. This gave a back-sight of 276 feet to run from into the heading. At each shaft a center was first set, with great care, about twenty-five feet off, and from this the line prolonged to two staples driven into the timbers on each side. On the mean of many sights being determined, the points on both staples were notched, the notches tested, and fine plummet lines dropped from them, the weights being steadied at the bottom, in water. Then the line was continued from these, as in ordinary mine surveying, in running from a shaft, the instrument being first approximately set up in line, and then moved sideways, until the hair exactly bisected the mean of the slight oscillations observable in the lines. Though the distance to be run from the shafts was not great, this care was necessary from the shortness of the back-sight, the distance between staples being only some $7\frac{1}{2}$ feet, and from the fact that the headings were through earth, it being very necessary in enlarging through earth to be able to have the crown bars closely located at equidistant spaces from center. On the headings between the shafts and slope meeting, the various runnings all tested closely; but it was the long line between the main east and west headings that required, of course, the most care, and caused the most anxiety. This line, at the east end, was simply continued on the grading, up into the heading, at first with one, and, subsequently, as the headings advanced, with two intermediate centers. At the west end, the line was at first run into the main heading (No. 1) down the slope, but as the enlargement in soft ground proceeded between the slope

and west end, in time a clear sight was obtained from the mouth of the tunnel to the slope, and thence into the heading, making two intermediate centers, as at the east end. It was always necessary to have a station where the slope came down, since the latter was driven, after meeting rock, sixteen feet wide — thirteen on the left and three on the right of center line, leaving at its foot about ten feet of space for passage on the right, as the line ran, and, of course, cutting off center line. The three feet on the right, however, were dressed off, subsequently, at the level of the heading, so as to give a clear back-sight to the mouth.

These east and west lines were repeatedly run and tested as the headings advanced, and, besides the work continually spent on them by the division and resident engineers, they were frequently checked by the principal assistant engineer. They finally tested within four hundredths (0.04) of a foot, or less than one half an inch. The levels were carried over the mountain by a series of test benches run until succeeding benches tested within 0.005 of a foot. On meeting, the face benches on either side were found to test within 0.015 of a foot, or less than one-fifth of an inch. Owing to the system of center cuts, used in blowing the rock, in which ten feet at a time were brought out, it was especially necessary that the chaining should be accurate, so that the distance apart of the headings might be safely determined. To measure over the mountain, two stout frames were made, steadied by weights on the legs. They each simply consisted of a vertical shaft with three legs, one movable. From a board nailed on the top of the shaft a fine plummet was hung. The two were put in line, the plummets centered by the transit, and a point at the top of one line leveled with a point near the bottom of the other, and the measurement thereon taken between the two with steel tapes. The hind frame was then moved on, and the chaining so carried up or down hill in successive steps. This method was found to be satisfactory; for, on the headings coming together, the distance apart, predicted and marked, was found to agree with the measured distance within fifty-two hundredths of a foot (0.52), or about six inches out in a total

chaining of about eight thousand feet, — four thousand through headings, and four thousand over the mountain, — the test measurement being brought down the slope on angle instead of in at the west entrance.

126. Ballast Stakes are set every 50 feet at the proper distance transversely, to indicate the width of the base of the ballast and by their tops the upper surface. The depth of the ballast is about 18 or 20 inches, or it is 12 or 14 inches below the lower surface of the tie. The center line of the track must again be retraced, stakes driven and centered; on curves every 50 or 25 feet, depending upon the curvature; on tangents every 200 feet.

CHAPTER VII.

FROGS AND SWITCHES.

DEFINITIONS.

127. The gauge of a track is the distance between the rails of the track. It is measured from the inside of the rails as from A to B , Fig. 79.



FIG. 79.

a. **The gauge line** is the line from which the gauge is measured. It is used instead of the rail in these calculations.

b. **The distance between tracks** is the perpendicular distance between the gauge lines of the tracks, as BA' .

c. **A turnout** is used to connect one track with another, as AB , Fig. 80.

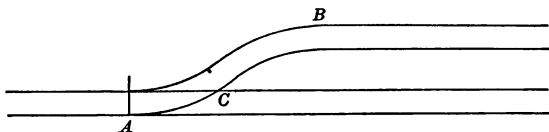


FIG. 80.

d. **A crossover** is used to pass from one to another of two parallel tracks, as AB , Fig. 81.

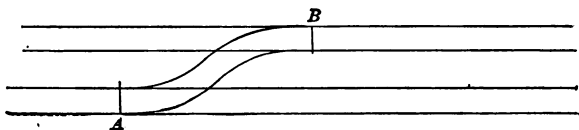


FIG. 81.

e. The **point of switch** is the point at which a turnout or crossover begins, as the point *A*, Fig. 80.

f. The **point of frog** is the point at which the gauge lines of two rails intersect, as at *C*, Fig. 80.

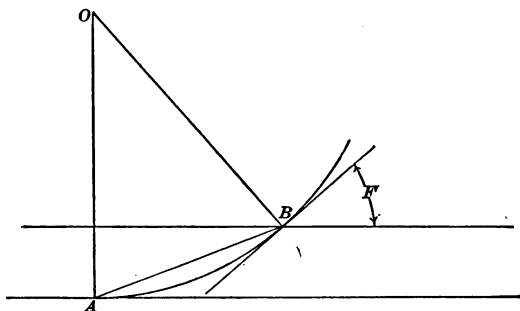


FIG. 82.

g. The **frog angle** is the angle formed by the gauge lines at the point of frog, as *F* at *B*, Fig. 82.

h. The **number of a frog** is found by constructing an isosceles triangle upon the lines enclosing the frog angle and dividing its altitude by its base.

If *A*, in Fig. 83, be the frog angle make $AB = AC$, and draw *AD* perpendicular to *BC*, then

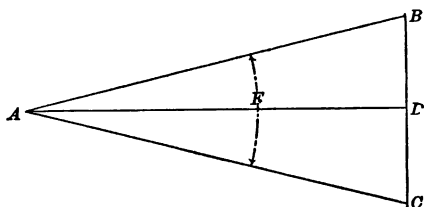


FIG. 83.

$$\text{the number of frog} = n = \frac{AD}{BC}.$$

If $AD = 8$ and $BC = 1$, then $n = 8$.

i. A **crossing frog** is formed by the intersection of two rails which are on the same sides of their respective tracks, as at *A* and *D*, Fig. 90. The frogs at *A*, *D*, *B* and *E*, taken collectively, are sometimes called a set of crossing frogs.

$$\text{hence} \quad AB = \frac{BE}{\sin A} = BE \operatorname{cosec} A,$$

$$\text{or} \quad L = \frac{g}{\sin \frac{1}{2} F} = g \operatorname{cosec} \frac{1}{2} F. \quad (119)$$

The isosceles triangle ACB gives

$$AB = 2 AC \sin \frac{1}{2} C,$$

$$\text{or} \quad L = 2 R \sin \frac{1}{2} F,$$

$$\text{and} \quad R = \frac{L}{2 \sin \frac{1}{2} F} = \frac{L}{2} \operatorname{cosec} \frac{1}{2} F. \quad (120)$$

EXAMPLE. — Given the frog angle $= 7^\circ 10'$, and the gauge 4.75 feet ; required the lead and the radius of the turnout.

$$\text{Ans. } L = 76.7'; R = 608.7'$$

129. Given the radius R , and the gauge g , of a turnout from a straight track, to find the lead L and the frog angle F , Fig. 84.

The right triangle HCB gives

$$\cos C = \frac{CH}{CB},$$

$$\text{or} \quad \cos F = \frac{R - g}{R}; \quad (121)$$

and the isosceles triangle ACB gives

$$AB = 2 AC \sin \frac{1}{2} C,$$

$$\text{or} \quad L = 2 R \sin \frac{1}{2} F. \quad (122)$$

EXAMPLES.

1. Given the radius 771.85, and the gauge 4.75 ; required the lead and the frog angle.

2. Given the radius 1151.92, and the gauge 4.75 ; required the lead and the frog angle.

TABLE FOR TURNOUTS FROM A STRAIGHT TRACK.*

No. of Frog.	Angle of Frog.	Lead of Turnout.	Radius of Turnout.†	Degree of Curve of Turnouts.†
4	14° 15' 0"	38.15	154.45	37° 47'
5	11° 25' 16"	47.74	239.9	24° 04'
6	9° 31' 38"	57.20	344.4	16° 42'
7	8° 10' 16"	66.67	467.9	12° 17'
8	7° 9' 10"	76.15	610.4	9° 24'
9	6° 21' 35"	85.67	771.85	7° 26'
10	5° 43' 29"	95.12	952.4	6° 01'
11	5° 12' 18"	104.61	1151.9	4° 59'
12	4° 46' 19"	114.10	1370.4	4° 11'
13	4° 24' 19"	123.58	1607.8	3° 34'
14	4° 5' 28"	133.07	1864.4	3° 04'
15	3° 49' 06"	142.58	2139.9	2° 41'

* $g = 4.75$.

† These refer to the rail running through the frog. For approximate degree of curve of turnout from a curved track, use degree of curve of turnout = degree of curve in table $\pm$ degree of curve of main track.

130. Given, in Fig. 85, the radius CB of the main track = R , and the frog angle F , to find the lead L and the radius R' of the turnout from the outside of the main track.

In the triangle CAB , $A - B = F$. For $A + C'AB = 180^\circ$, and the isosceles triangle $C'AB$ gives $C'AB = C'BA$ and $C'BA + B + CBE = 180^\circ$. Therefore, since

$$CBE = F, A + C'AB = C'BA + B + F, \text{ or } A - B = F.$$

Again

$$CB - CA : CB + CA = \tan \frac{1}{2}(A - B) : \tan \frac{1}{2}(A + B),$$

$$\text{or} \quad \tan \frac{1}{2}(A + B) = \frac{(CB + CA) \tan \frac{1}{2}(A - B)}{CB - CA},$$

or, substituting values, there results,

$$\tan \frac{1}{2}(A + B) = \frac{(2R - g) \tan \frac{1}{2}F}{g}. \quad (123)$$

The half sum of A and B being thus found, and $\frac{1}{2} (A - B)$ being equal to $\frac{F}{2}$, A and B are readily determined.

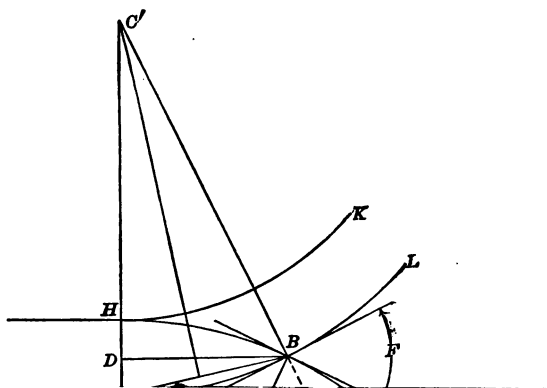


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8	7° 9' 10"	76.15	610.4	9° 24'
9	6° 21' 35"	85.67	771.85	7° 26'
10	5° 43' 29"	95.12	952.4	6° 01'
11	5° 12' 18"	104.61	1151.9	4° 59'
12	4° 46' 19"	114.10	1370.4	4° 11'
13	4° 24' 19"	123.58	1607.8	3° 34'
14	4° 5' 28"	133.07	1864.4	3° 04'
15	3° 49' 06"	142.58	2139.9	2° 41'

TABLE FOR TURNOUTS FROM A STRAIGHT TRACK.

$$g = 4' 8\frac{1}{4}"$$

No. of Frog.	Angle of Frog.	Lead of Turnout.	Radius of Turnout.	Degree of Curve of Turnout.
4	14° 15' 0"	37.96	153.0	38° 09'
5	11° 25' 16"	47.32	237.8	24° 17'
6	9° 31' 38"	56.70	341.4	16° 51'
7	8° 10' 16"	66.08	463.8	12° 23'
8	7° 9' 10"	75.48	605.0	9° 29'
9	6° 21' 35"	84.88	765.1	7° 30'
10	5° 43' 29"	94.27	943.7	6° 04'
11	5° 12' 18"	103.69	1141.8	5° 01'
12	4° 46' 19"	113.10	1358.4	4° 13'
13	4° 24' 19"	122.51	1593.9	3° 30'
14	4° 5' 28"	131.91	1847.8	3° 06'
15	3° 49' 06"	141.33	2121.1	2° 42'

The half sum of A and B being thus found, and $\frac{1}{2} (A - B)$ being equal to $\frac{F}{2}$, A and B are readily determined.

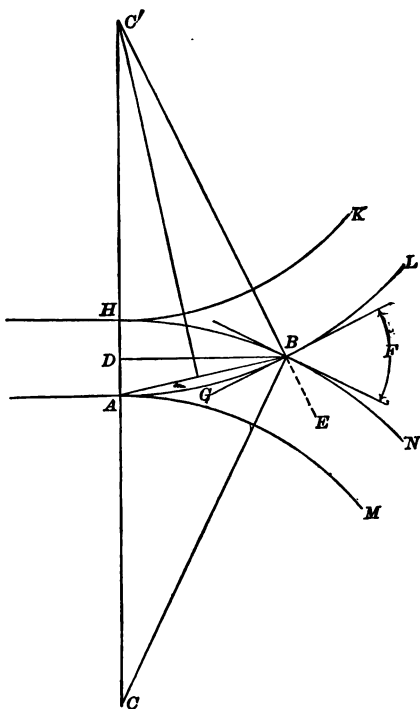


FIG. 85.

Then

$$C = 180 - (A + B),$$

and the exterior angle

$$CBE = C + C' = F,$$

or

$$C' = F - C.$$

(124)

In the triangle ABC ,

$$AB = \frac{\sin C}{\sin A} BC,$$

or

$$L = \frac{\sin C}{\sin A} R. \quad (125)$$

In the triangle ABC' ,

$$C'B = \frac{AB}{2 \sin \frac{1}{2} C'},$$

or
$$R' = \frac{L}{2 \sin \frac{1}{2} C'}. \quad (126)$$

EXAMPLE.—In a turnout from the outside of a 6° curve with a number 10 frog, find the lead, and radius of the turnout.

131. Given, in Fig. 85, the radius CB of the main track $= R$, and the radius $C'B$ of the turnout $= R'$, to find the lead $AB = L$ and the frog angle F .

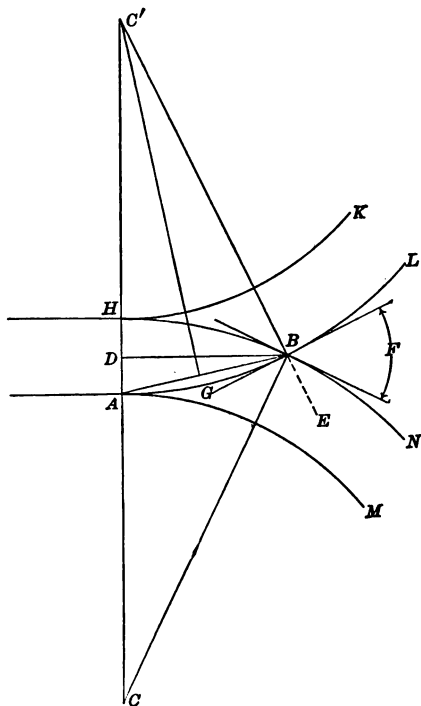


FIG. 85.

Draw BD and $C'G$ perpendicular to CH and AB respectively. CAC' is a straight line, for the curves AM and AL are tangent to each other at A . In the triangle CBC' , $CC' = R + R' - g$, hence all the sides are known, and we have the proportion

$$CC' : BC + BC' = BC - BC' : CD - C'D,$$

or $R + R' - g : R + R' = R - R' : CD - C'D.$

$$\therefore CD - C'D = \frac{(R + R')(R - R')}{R + R' - g}.$$

The difference between CD and $C'D$ being thus found, and having their sum $= R + R' - g$, CD and $C'D$ are readily determined.

In the triangle BCD ,

$$\cos C = \frac{CD}{BC} = \frac{CD}{R}, \quad (127)$$

and in the triangle $C'BD$,

$$\cos C' = \frac{C'D}{C'B} = \frac{C'D}{R'}; \quad (128)$$

now the angle CBE , which is $= F$ = the sum of the angles at C and C' ,

or, $F = C + C'. \quad (129)$

The isosceles triangle $AC'B$ gives

$$L = 2R' \sin \frac{1}{2} C'. \quad (130)$$

EXAMPLE.—The radius of a turnout from the outside of a 4° curve $= 1060.22$. Find the lead and frog angle.*

$$\text{Ans. } L = 76.27 \text{ feet; } F = 7^\circ 9'.$$

132. Given the frog angle F , the radius $CH = CB = R$ of the main track, Fig. 86, to find the lead $AB = L$, and the radius $C'A = C'B = R'$ of the turnout from the inside of a curved track.

Let AM represent the outside rail of the main track. Then C , C' , and A are in the same straight line, since the arcs AM and AL are tangent at A .

* When g is not given use 4.75.

In the triangle ACB , $B - A = F$. For F being the angle between the tangents at B , and $C'B$ and CB being radii, it follows, therefore, that

$$C'BC = F = B - C'BA = B - A.$$

Then

$$F \equiv B - A.$$

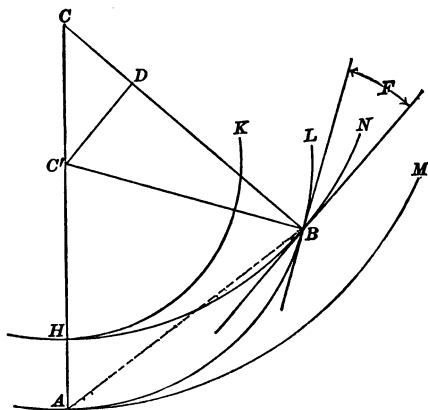


FIG. 86.

Now $AC - BC : AC + BC = \tan \frac{1}{2}(A - B) : \tan \frac{1}{2}(A + B)$;

hence, $\tan \frac{1}{2}(A+B) = \frac{(AC+BC) \tan \frac{1}{2}(A-B)}{AC-BC},$

or, substituting, there results

$$\tan \frac{1}{2}(A + B) = (2R + g) \frac{\tan \frac{1}{2}F}{g}.$$

With this half sum of A and B , and $\frac{F}{2}$ the half difference,
 A and B may be found.

Again,

$$C = 180 - (A + B),$$

and

$$AB = \frac{BC \cdot \sin C}{\sin A},$$

or,

$$L = \frac{R \cdot \sin C}{\sin A}. \quad (131)$$

The exterior angle at $C' = C + F$, and the isosceles triangle $AC'B$, gives

$$AC' = \frac{AB}{2 \sin \frac{1}{2} C'},$$

or,
$$R' = \frac{L}{2 \sin \frac{1}{2} C'} = \frac{L}{2} \operatorname{cosec} \frac{1}{2} C'. \quad (132)$$

133. In Fig. 86, given the radii $CB = R$, $C'B = R'$, to find the frog angle and the lead.

In the triangle $CC'B$, $CC' = CA - C'A = R + g - R'$. The three sides of the triangle are therefore known, and drawing the perpendicular $C'D$, we have from a well-known proposition,

$$BD - CD = \frac{(BC' + CC')(BC' - CC')}{BC},$$

or, substituting, there results

$$BD - CD = \frac{(R + g)}{R} (2R' - R - g).$$

With this difference of BD and CD , and $CB = R$ as their sum, find BD and CD . Then, since the angle $C'BC = F$,

$$\cos F = \frac{BD}{R'}, \quad (133)$$

and
$$\cos C'CB = \frac{CD}{C'C} = \frac{CD}{R + g - R'}.$$

In the isosceles triangle $AC'B$, the angle

$$AC'B = C'BC + BCC';$$

hence

$$AB = 2 C'B \sin \frac{1}{2} AC'B,$$

or,

$$L = 2 R' \sin \frac{1}{2} AC'B. \quad (134)$$

EXAMPLES.

1. Given the frog angle $= 5^\circ 43' 29''$, the radius of the main track $= 1436.69$, to find the lead and the radius of the turnout.

2. Given the radius of the main track $= 955.37$, and that of the turnout $= 477.8$, to find the frog angle and the lead.

$$\text{Ans. } F = 5^\circ 43' 29''; L = 94.83.$$

134. Given the angle of the frogs $F = F'$, the gauge g , and the distance between the tracks b , Fig. 87, of a crossover on straight tracks, to find the distance $F'K$.

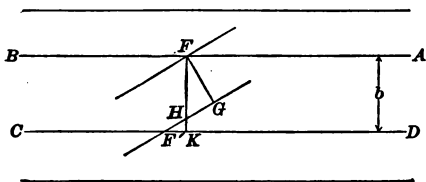


FIG. 87.

In the triangle HFG , the angle $HFG = F$, and

$$FH = \frac{g}{\cos F} = g \sec F.$$

In the triangle $HF'K$, the angle at $F' = F$, and

$$HK = b - FH = b - g \sec F,$$

therefore $F'K = (b - g \sec F) \cot F.$ (135)

135. Given the frog angles F and F' , the gauge g , and the distance between tracks b , Fig. 88, of a crossover on straight tracks, to find the distance CE and the radius $DO = R$.

Make DE and AB perpendicular to BE , and AG parallel to it. Make $AC = g$, and draw AK parallel to the tangent of the frog at C . The angle $LAG = F'$.

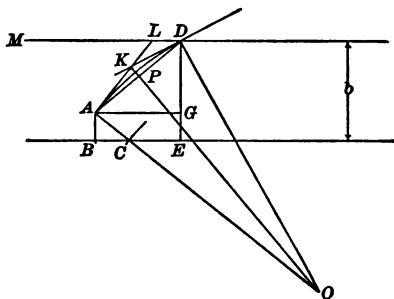


FIG. 88.

In the triangle KLD , the angle $LDK = F$, and the exterior angle $KLM = F'$, hence the angle $LKD = AOD = F' - F$.

In the triangle ACB , $AC = g$, $A = F'$, $AB = AC \cos A = g \cos F'$, and $BC = g \sin F$.

In the triangle DGA , $DG = b - GE = b - g \cos F'$, and $DAG = LAG - [LAD = \frac{1}{2}(F' - F)] = \frac{1}{2}(F' + F),$

$$AG = DG \cot DAG = (b - g \cos F') \cot \frac{1}{2}(F' + F),$$

and $CE = BE - BC = AG - BC,$

or $CE = (b - g \cos F') \cot \frac{1}{2}(F' + F) - g \sin F'. \quad (136)$

$$AD = \frac{DG}{\sin DAG} = (b - g \cos F') \operatorname{cosec} \frac{1}{2}(F' + F),$$

and the radius

$$AO = DO = \frac{DP}{\sin DOP} = \frac{\frac{1}{2}AD}{\sin \frac{1}{2}(F' - F)};$$

substituting the value of AD found above, we obtain

$$R = \frac{b - g \cos F'}{2 \sin \frac{1}{2}(F' + F) \sin \frac{1}{2}(F' - F)}; \quad (137)$$

or $R = \frac{b - g \cos F'}{2} \operatorname{cosec} \frac{1}{2}(F' + F) \operatorname{cosec} \frac{1}{2}(F' - F). \quad (137a)$

EXAMPLES.

1. Given, in Fig. 87, $F = F' = 7^\circ 9'$, the gauge = 4.75, and $b = 7.417$, to find $F'K$.

2. Given, in Fig. 88, $F = 7^\circ 9'$, $F' = 9^\circ 32'$, $g = 4.75$, and $b = 7.42$, to find CE and R .

136. Given the radius $FO = R$ of one rail, and distance b between two concentric tracks, and the angles F and F' of two frogs in a crossover between them, Fig. 89, to find the distance FD measured on a chord of the rail BFD and $CO' =$ radius of the outer rail of the crossover.

Let MC and BD represent the gauge lines of the rails which pass through the frogs and A , C , one rail of the crossover. Draw the radii AO , CO , AO' , and CO' ; also FO , AC , and FD .

In the triangle AOF the exterior angle $OFO' = F$, $AF = g$, and $FO = R$, so that we have two sides and the included angle given, whence

$$R + g : R - g = \tan \frac{1}{2}F : \tan \frac{1}{2}(OAF - AOF),$$

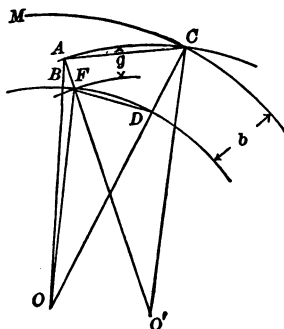


FIG. 89.

$$\text{or} \quad \tan \frac{1}{2}(OAF - AOF) = \tan \frac{1}{2}F \frac{(R - g)}{R + g}.$$

With this half difference, and $\frac{1}{2}F$ as the half sum, the angles A and O are readily found.

Then, by the law of sines,

$$\sin FAO : \sin AFO = FO : OA,$$

$$\text{or} \quad OA = \frac{R \sin F}{\sin FAO} = R \sin F \operatorname{cosec} FAO. \quad (138)$$

In the triangle AOC we now know OA , $OC = R + b$, and the difference of the angles A and $C = OAF + F'$, for the angle $OAC = OAF + O'AC$, and $OCA = O'AC - OCO'$. Now $OCO' = F'$, but $O'CA - OCA = F'$; hence $OAC - ACO = OAF + F'$.

Then, having the two sides AO and CO , and the difference of the angles opposite them, we obtain, by the law of tangents,

$$CO + AO : CO - AO = \tan \frac{1}{2}(OAC + OCA) : \tan \frac{1}{2}(OAC - OCA);$$

$$\therefore \tan \frac{1}{2}(OAC + OCA) = \frac{CO + AO}{CO - AO} \tan \frac{1}{2}(OAC - OCA),$$

$$\text{or} \quad \tan \frac{1}{2}(OAC + OCA) = \frac{R + b + AO}{R + b - AO} \tan \frac{1}{2}(F' + OAF).$$

With this half sum and $\frac{F' + OAF}{2}$ as the half difference, we find $OAC =$ their sum and OCA their difference. Then, by the law of sines,

$$AC = \frac{OC \sin AOC}{\sin OAC}. \quad (139)$$

In the triangle AOC , $O'AC = O'CA = OCA + O'CO$ and $AOC = 180^\circ - 2 O'CA$, there are then known all the angles and the side AC , so that

$$OC = R' = \frac{AC \sin O'AC}{\sin AOC}. \quad (140)$$

In the isosceles triangle FOD , $FOD = BOD - BOF$, and

$$FD = 2 FO \sin \frac{1}{2}FOD,$$

$$\text{or} \quad FD = 2 R \sin \frac{1}{2}FOD. \quad (141)$$

In the triangle EDC the angle $E = 90 + F$, the angle at $D = 90 - F'$, $EC = R$, and $DC = R + g$. Then

$$\sin D = \frac{\sin E \times EC}{DC} = \frac{\sin(90 + F) R}{R + g},$$

or
$$\sin D = \frac{R}{R + g} \cos F,$$

and
$$F' = 90 - D. \quad (144)$$

The angle $ECD = F' - F$, and

$$D = \frac{\sin ECD \times EC}{\sin EDC} = \frac{R \sin(F' - F)}{\cos F'}. \quad (145)$$

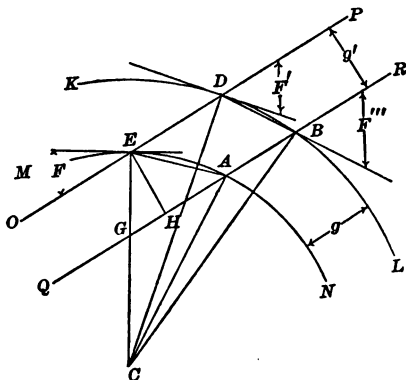


FIG. 91.

The right triangle EHG gives

$$EG = \frac{EH}{\cos GEH} = \frac{g'}{\cos F'}.$$

In the triangle CGA , $CA = R$, $CG = R - EG$ and angle $CGA = 90 + F$. Then

$$\sin CAG = \frac{\sin CGA \times CG}{AC} = \frac{\cos F}{R} \left(R - \frac{g'}{\cos F'} \right) = \cos F - \frac{g'}{R}.$$

Now

$$CAG = 90 - F'';$$

$$F'' = 90 - CAG. \quad (146)$$

The angle $ECA = F'' - F$.

The isosceles triangle ACE , gives

$$EA = EC \times 2 \sin \frac{1}{2} ACE,$$

$$\text{or} \quad EA = 2R \sin \frac{1}{2} (F'' - F). \quad (147)$$

The triangle ACB gives

$$\sin ABC = \frac{\sin CAB \times AC}{CB} = \frac{R}{R + g} \cos F'',$$

$$\text{and} \quad F''' = 90 - ABC. \quad (148)$$

The angle $ACB = F''' - F''$,

$$AB = \frac{\sin ACB \times BC}{\sin BAC},$$

$$\text{or} \quad AB = \frac{(R + g) \sin (F''' - F'')}{\cos F''}. \quad (149)$$

In the triangle BCD the angle $C = F''' - F'$, and

$$DB = 2 DC \sin \frac{1}{2} C,$$

$$\text{or} \quad DB = 2(R + g) \sin \frac{1}{2} (F''' - F'). \quad (150)$$

EXAMPLES.

1. Given, in Fig. 90, the angle $F = 9^\circ 31' 38''$ (No. 6 frog) to find EA and ED .

2. Given, in Fig. 91, a 4° curve, and a No. 6 frog at E , required F' , F'' , F''' , and distances EA , DB , ED , and AB .

139. Given the radii $AC = EC = R$, and $AC' = BC' = R'$, of two curved tracks crossing each other, Fig. 92, and forming the angle F at the point E . Required the angles F' , F'' , and F''' , formed at A , D , and B , respectively, and the distances EA , ED , AB , and DB .

In the triangle CEC' we have given $CE = R$, $C'E = R' + g'$, and the included angle $CEC' = F$. Then

$$\begin{aligned} \tan \frac{1}{2} (ECC' - EC'C) &= \frac{(EC' - EC) \tan \frac{1}{2} (ECC' + EC'C)}{EC' + EC} \\ &= \frac{R' + g' - R}{R' + g' + R} \tan \frac{1}{2} F. \end{aligned}$$

With this half difference and $\frac{180^\circ - F}{2}$, as the half sum, the angles ECC' and $EC'C$ are readily found.

This triangle also gives

$$CC' = \frac{EC \sin ECC'}{\sin EC'C} = \frac{R \sin F}{\sin EC'C}.$$

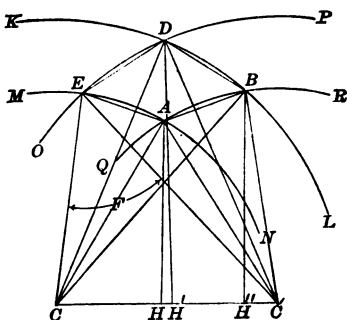


FIG. 92.

Now, in the triangle ACC' , CC' is given by the last equation, the side $AC = R$, $AC' = R'$, hence the angles may be computed.

Draw AH perpendicular to CC' , then

$$C'H - CH : C'A - CA = C'A + CA : CC',$$

$$\text{or } C'H - CH = \frac{(R' - R)(R' + R)}{CC'} = \frac{R'^2 - R^2}{CC'}.$$

This half difference of the segments of the base added to their half sum will give the longer segment $C'H$, and being subtracted from the half sum will give the shorter CH . Then

$$\cos ACC' = \frac{CH}{CA}, \quad \cos AC'C = \frac{C'H}{C'A},$$

and

$$F' = 180^\circ - (ACC' + AC'C). \quad (151)$$

Now, in the isosceles triangle ACE , $ECA = ECC' - ACC'$, and $CA = CE = R$, and the included angle C are known, hence

$$EA = 2R \sin \frac{1}{2} ACE. \quad (152)$$

In the triangle CDC' , $CD = R + g$, $C'D = R' + g'$, and CC' is known, hence

$$CH' - C'H' = \frac{(R + g)^2 - (R' + g')^2}{CC'},$$

and $\cos DCH' = \frac{CH'}{CD}$, $\cos DC'H' = \frac{C'H'}{C'D}$,

and $CDC' = F'' = 180^\circ - (DCH' + DC'H')$. (153)

Again, the angle $DC'C - EC'C = EC'D$.

In the isosceles triangle $C'DE$,

$$C'E = C'D = R' + g', \text{ and } ED = 2(R' + g') \sin \frac{1}{2} EC'D. \quad (154)$$

In the triangle CBC' , $CB = R + g$, $C'B = R'$, and CC' is known, hence

$$CH'' - C'H'' = \frac{(R + g)^2 - R'^2}{CC'}.$$

Proceeding as above, with the half difference and half sum we obtain $C'H''$ and CH'' , then

$$\cos BCC' = \frac{CH''}{CB} = \frac{CH''}{R + g},$$

$$\cos BC'C = \frac{C'H''}{C'B} = \frac{C'H''}{R'},$$

and $F''' = CBC' = 180 - (BCC' + BC'C)$. (155)

In the isosceles triangle $AC'B$, $AC' = BC' = R'$, and the angle $AC'B = BC'C - AC'C$, hence

$$AB = 2R' \sin \frac{1}{2} AC'B. \quad (156)$$

In the isosceles triangle DCB ,

$$DC = BC = R + g,$$

$$DCB = DCC' - BCC',$$

and $DB = 2(R + g) \sin \frac{1}{2} DCB$. (157)

EXAMPLE. — Given, in Fig. 92, a 1° curved track, crossing another of 4° , and a number 6 frog at E . Find F' , F'' , F''' , and the chords EA , ED , AB , and DB .

140. If the tracks cross as in Fig. 93 then the solution is the same, except that $CEC' = 180^\circ - F$, and $F = ECC' + EC'C$.

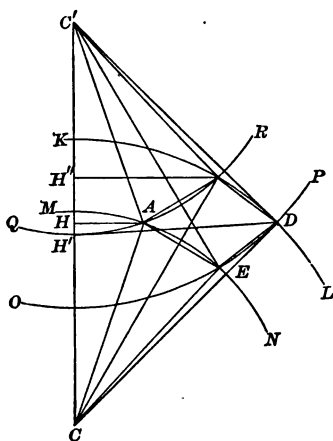


FIG. 93.

The half sum of ECC' and $EC'C = \frac{F}{2}$, and (151) becomes $F' = ACC' + AC'C$; (153) becomes $F'' = DCH' + DC'H'$; (155) becomes $F''' = BCC' + BC'C$.

EXAMPLE.—Given, Fig. 93, a 1° curved track, crossing another of 2° , and a No. 8 frog at E , to find F' , F'' , F''' , and the chords ED , EA , BD , and BA .

141. Given F , the angle of intersection of two straight tracks, Fig. 94, to find the radii AO and MO , and the lengths of the curved rails AB and ML , of a crossing slip connecting the tracks.

Draw the radii AO and BO , and connect C and O . By Article 137, Fig. 90, find the distances GC , GK , and CH , HK , and assume GA as small as the construction of the frog at G will permit.

Then, since the arc ADB must be tangent to GC and CH at A and B respectively, $AC = CB = GC - GA$. F is the

angle at the vertex, and AC the tangent distance of the curve ADB . Hence

$$AO = AC \cot \frac{1}{2} F. \quad (158)$$

$$MO = AO - g. \quad (159)$$

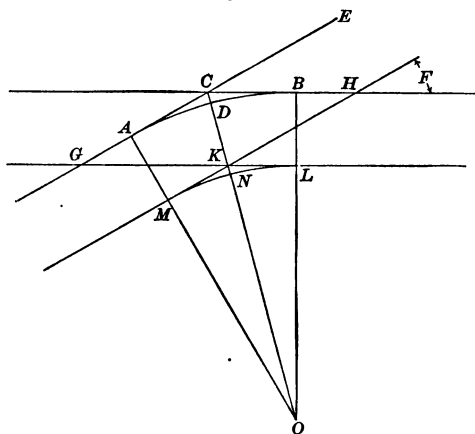


FIG. 94.

The length of the arc

$$AB = AO \times 3.1416 \times \frac{F}{360}, \quad (160)$$

and the arc

$$ML = MO \times 3.1416 \times \frac{F}{360}. \quad (161)$$

EXAMPLE. — Given, in Fig. 94, $F = 9^\circ 31' 38''$, to find the radii and lengths of the curved rails AB and ML , GA being 5 feet.

142. In a crossing of a curved track by a straight track, Fig. 95. Having given the radii of the rails of the curved track, and the angle of the frog at E , to find AO' , MO' , the radii, and the lengths AB and MN of the curved rails of a crossing slip connecting the tracks.

By Article 138, Fig. 91, find the angles F' , F'' , and F''' , of the frogs at C , K , and H respectively, and the distances EC , EK , CH , and HK .

Draw the radii EO , CO , BO , and HO . Assume BH as short as the construction of the frog at H will admit of. Draw DB tangent to CBH , and AO' at right angles to ED , making $AD = DB$.

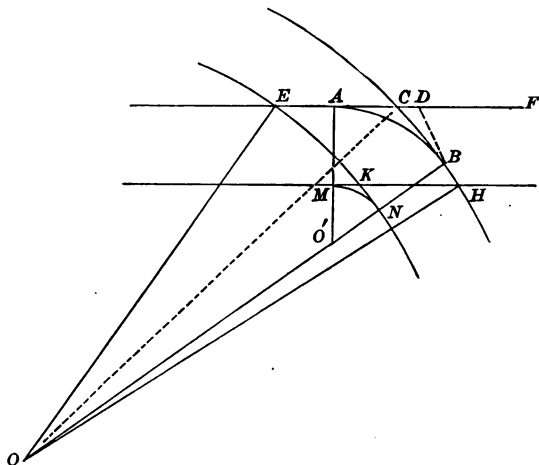


FIG. 95.

In the isosceles triangle BOH ,

$$\sin \frac{1}{2} O = \frac{BH}{2BO},$$

the angle

$$COB = COH - BOH = F'' - F' - BOH,$$

and the chord

$$CB = 2 \sin \frac{1}{2} COB \times CO. \quad (162)$$

In the triangle DCB , $CBD = \frac{1}{2} COB$, $DCB = F' + \frac{1}{2} COB$, and the exterior angle $FDB =$ their sum $= F' + COB$.* Then, by the law of sines, CD and DB are readily found. It will now be seen that FDB is the angle at the vertex, and DB the tangent distance of the curve AB . Then

$$AO' = BO' = BD \cot \frac{1}{2} FDB. \quad (163)$$

$$MO' = BO' - g. \quad (164)$$

* When the slip rails are on the outside of the curve $FCB = F' - \frac{1}{2} COB$,
and $FDB = F' - COB$.

The length of the arc

$$AB = \frac{AO' \times 3.1416}{360} \times \text{the angle } FDB \text{ in degrees.} \quad (165)$$

The length of the arc

$$MN = \frac{MO' \times 3.1416}{360} \times \text{the angle } FDB \text{ in degrees.} \quad (166)$$

EXAMPLE. — Given, Fig. 95, the curved track on a 2° curve, and the frog at E , a No. 6 frog, to find the radii and lengths of the curved rails AB and MN , BH being $4\frac{1}{2}$ feet.

143. Given the radii of the rails of two curved tracks which cross each other, as in Fig. 96, the angle of the frog at $G = F$, and AG , to find the radii and lengths of the curved rails AB and EF , of a crossing slip connecting the tracks.

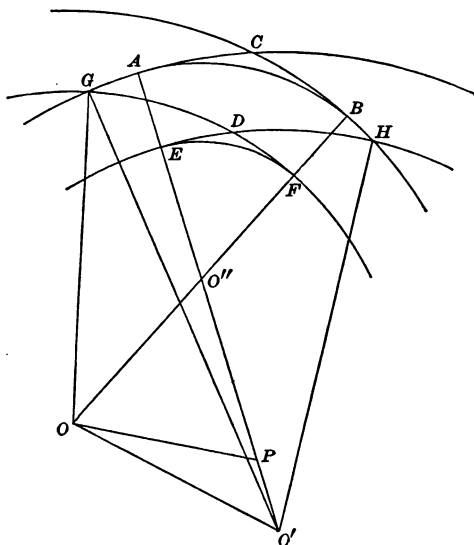


FIG. 96.

O and O' being the centers of the rails GC and GF respectively, and the figure completed as shown, O'' will be the center of the arcs AB and EF .

Let the radius $GO = R$ and $GO' = R'$, then $BO = R + g$.

By Article 139, Fig. 92, find the angles F' , F'' , and F''' of the frogs at C , D , and H respectively; also the chords GC , GD , CH , and the side OO' , and angle at O' of the triangle GOO' .

In the triangle $GO'A$,

$$\sin \frac{1}{2} GO'A = \frac{GA}{2 GO'}.$$

In the triangle $OO''O'$, the angle

$$O' = OO'G + GO'A,$$

and $O'O - O'O = R' - R - g;$ (167)

for $O'O = AO' - AO''$, and $O'O = OB - O'B$, also $O'B = AO''$.

Lay off $O'P = O'O$ on $O'O'$, then

$$O'P = R' - R - g. \quad (168)$$

In the triangle $OP O'$,

$$\tan \frac{1}{2} (P - O) = \frac{OO' - O'P}{OO' + O'P} \times \tan \left(90^\circ - \frac{O'}{2} \right).$$

With this value of the half difference, and $\left(90^\circ - \frac{O'}{2} \right)$ as the value of the half sum, the angles P and O are readily found. Then

$$OP = \frac{\sin O'}{\sin P} \times OO'.$$

The exterior angle $OP O'' = O + O'$.

The isosceles triangle $OO''P$ gives

$$O'O = \frac{OP}{2 \cos O''OP}.$$

Then the radius $O'B$ of the arc $AB = OB - OO''$,

or $O'B = R + g - OO'.$ (169)

The radius FO'' of the arc $EF = O'B - g$,

or $FO'' = R - OO'.$ (170)

The length of the arc

$$AB = O'B \times 3.1416 \times \frac{AO'B}{360}, \quad (171)$$

and the length of the arc

$$EF = FO'' \times 3.1416 \times \frac{AO'B}{360}. \quad (172)$$

TRIGONOMETRIC FORMULAS.

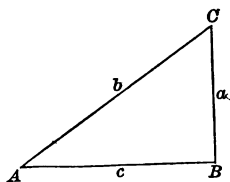


FIG. 98.

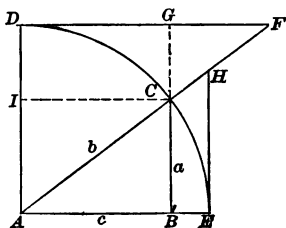


FIG. 99.

In Fig 99, let DCE be the arc of a quadrant, ABC a right triangle, the angle BAC subtended by the arc $CE = A$, and consider the radius $AC = \text{unity}$. Then

$$BC = \sin A.$$

$$AF = \text{cosec } A.$$

$$AB = \cos A.$$

$$BE = \text{versin } A.$$

$$HE = \tan A.$$

$$DI = \text{coversin } A.$$

$$DF = \cot A.$$

$$CH = \text{exsec } A.$$

$$AH = \sec A.$$

$$CF = \text{coexsec } A.$$

Using the small letters a, b, c , to represent the sides of a right triangle in Fig. 98 or 99, we may write

$$\sin A = \frac{a}{b}; \quad \text{cosec } A = \frac{b}{a}; \quad \therefore \sin A = \frac{1}{\text{cosec } A}.$$

$$\cos A = \frac{c}{b}; \quad \sec A = \frac{b}{c}; \quad \therefore \cos A = \frac{1}{\sec A}.$$

$$\tan A = \frac{a}{c}; \quad \cot A = \frac{c}{a}; \quad \therefore \tan A = \frac{1}{\cot A}.$$

SOLUTION OF RIGHT TRIANGLES.

Required.	Given.	Formulas.
A, C, c	a, b	$\sin A = \cos C = \frac{a}{b}; \quad c = \sqrt{(b+a)(b-a)}.$
A, C, b	a, c	$\tan A = \cot B = \frac{a}{c}; \quad b = \sqrt{a^2 + c^2}.$
C, b, c	A, a	$C = 90^\circ - A; \quad c = a \cot A; \quad b = a \operatorname{cosec} A.$
C, a, c	A, b	$C = 90^\circ - A; \quad a = b \sin A; \quad c = b \cos A.$
C, a, b	A, c	$C = 90^\circ - A; \quad a = c \tan A; \quad b = c \sec A.$

SOLUTION OF OBLIQUE TRIANGLES.

Required.	Given.	Formulas.
b	A, B, a	$b = \frac{a \sin B}{\sin A}$
B	A, a, b	$\sin B = \frac{b \sin A}{a}$
$\frac{1}{2}(A+B)$	a, b, C	$\frac{1}{2}(A+B) = \frac{1}{2}(180 - C)$
$\frac{1}{2}(A-B)$		$\tan \frac{1}{2}(A-B) = \frac{a-b}{a+b} \tan \frac{1}{2}(A+B)$
A		$A = \frac{1}{2}(A+B) + \frac{1}{2}(A-B)$
B	a, b, c	$B = \frac{1}{2}(A+B) - \frac{1}{2}(A-B)$
A		If $s = \frac{1}{2}(a+b+c)$, $\sin \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}}$
		$\cos \frac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}}$
		$\tan \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$
		$\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$
Area		Area $= \sqrt{s(s-a)(s-b)(s-c)}$
Area	A, b, c	Area $= \frac{1}{2}bc \sin A$
Area	A, B, c	Area $= \frac{c^2 \sin A \sin B}{2 \sin(A+B)}$

GENERAL FORMULAS.

$$\sin A = \sqrt{1 - \cos^2 A} = \tan A \cos A.$$

$$\sin A = 2 \sin \frac{1}{2} A \cos \frac{1}{2} A.$$

$$\sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{\frac{1}{2}(1 - \cos A)}.$$

$$\cos A = \frac{1}{\sec A} = \sqrt{1 - \sin^2 A} = \cot A \sin A.$$

$$\cos A = 1 - 2 \sin^2 \frac{1}{2} A = 1 - \operatorname{vers} A.$$

$$\cos A = \sqrt{\frac{1}{2} + \frac{1}{2} \cos 2 A} = \cos^2 \frac{1}{2} A - \sin^2 \frac{1}{2} A.$$

$$\tan A = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1}.$$

$$\tan A = \frac{\sqrt{1 - \cos^2 A}}{\cos A} = \frac{\sin 2 A}{1 + \cos 2 A}.$$

$$\tan A = \frac{1}{\cot A} = \frac{1 - \cos 2 A}{\sin 2 A}.$$

$$\cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1}.$$

$$\cot A = \frac{\sin 2 A}{1 - \cos 2 A} = \frac{1 + \cos 2 A}{\sin 2 A}.$$

$$\sec A = \frac{1}{\cos A} = \text{the reciprocal of any expression for } \cos A.$$

$$\operatorname{cosec} A = \frac{1}{\sin A} = \text{the reciprocal of any expression for } \sin A.$$

$$\operatorname{vers} A = 1 - \cos A = 2 \sin^2 \frac{1}{2} A.$$

$$\operatorname{exsec} A = \sec A - 1 = \frac{\operatorname{vers} A}{\cos A}.$$

$$\sin \frac{1}{2} A = \sqrt{\frac{1 - \cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}}.$$

$$\cos \frac{1}{2} A = \sqrt{\frac{1 + \cos A}{2}}.$$

$$\tan \frac{1}{2} A = \frac{\tan A}{1 + \sec A} = \frac{1 - \cos A}{\sin A} = \frac{\sin A}{1 + \cos A}.$$

$$\cot \frac{1}{2} A = \frac{1 + \cos A}{\sin A} = \frac{\sin A}{1 - \cos A}.$$

$$\sin 2A = 2 \sin A \cos A.$$

$$\cos 2A = \cos^2 A - \sin^2 A = 2 \cos^2 A - 1.$$

$$\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}.$$

$$\cot 2A = \frac{\cot^2 A - 1}{2 \cot A}.$$

$$\sin (A \pm B) = \sin A \cos B \pm \cos A \sin B.$$

$$\cos (A \pm B) = \cos A \cos B \mp \sin A \sin B.$$

$$\tan (A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}.$$

$$\sin A + \sin B = 2 \sin \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B).$$

$$\sin A - \sin B = 2 \cos \frac{1}{2} (A + B) \sin \frac{1}{2} (A - B).$$

$$\cos A + \cos B = 2 \cos \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B).$$

$$\cos B - \cos A = 2 \sin \frac{1}{2} (A + B) \sin \frac{1}{2} (A - B).$$

$$\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin (A + B) \sin (A - B).$$

$$\cos^2 A - \sin^2 B = \cos (A + B) \cos (A - B).$$

$$\tan A \pm \tan B = \frac{\sin (A \pm B)}{\cos A \cos B}.$$

$$\cot A \pm \cot B = \frac{\pm \sin (A \pm B)}{\sin A \sin B}.$$

MISCELLANEOUS FORMULAS.

Required.	Given.	Formulas.
<i>Area of</i>		
Trapezoid	Parallel sides = m and n Perp. dist. bet. them = p	$\frac{p}{2} (m + n)$
Regular Polygon	Length of side = l Number of sides = n	$\frac{nl^2}{4} \cot \frac{180^\circ}{n}$
Circle	Radius = r	πr^2 [$\pi = 3.1416$]
Ellipse	Semi-axes = a and b	πab
Parabola	Base = b , height = h	$\frac{2}{3} bh$
<i>Surface of</i>		
Cone	Radius of base = r Slant height = s	πrs
Cylinder	Radius = r , height = h	$2 \pi rh$
Sphere	Radius = r	$4 \pi r^2$
Zone	Height = h Radius of its sphere = r	$2 \pi rh$
<i>Volume of</i>		
Prism or cylinder	Area of base = b Height = h	bh
Pyramid or cone	Area of base = b Height = h	$\frac{bh}{3}$
Frustum of Pyramid or cone	Area of bases = b and b' Height = h	$\frac{h}{3} (b + b' + \sqrt{bb'})$
Sphere	Radius = r	$\frac{4}{3} \pi r^3$

TABLES.

The plates for Table IX and for I and II in the Appendix were prepared by Messrs. J. S. Cushing & Co., Norwood, Mass. All other tables except Table XI are printed from electrotypes furnished by Messrs. John Wiley and Sons, New York.

TABLE I.—RADII.

Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.
0° 0'	Infinite	1° 0'	5729.65	2° 0'	2864.93	3° 0'	1910.09	4° 0'	1432.69
1	34377.5	1	5635.72	1	2841.26	1	1899.53	1	1426.74
2	171887.	2	5544.83	2	2817.97	2	1889.09	2	1420.85
3	114592.	3	5456.82	3	2795.06	3	1878.77	3	1415.01
4	85943.7	4	5371.56	4	2772.53	4	1868.56	4	1409.21
5	68754.9	5	5288.92	5	2750.85	5	1858.47	5	1403.46
6	57295.8	6	5208.79	6	2728.52	6	1848.48	6	1397.76
7	49110.7	7	5131.05	7	2707.04	7	1838.59	7	1392.10
8	42971.8	8	5055.59	8	2685.89	8	1828.82	8	1386.49
9	38197.2	9	4982.33	9	2665.08	9	1819.14	9	1380.92
10	34377.5	10	4911.15	10	2644.58	10	1809.57	10	1375.40
11	31252.3	11	4841.98	11	2624.39	11	1800.10	11	1369.92
12	28647.8	12	4774.74	12	2604.51	12	1790.73	12	1364.49
13	26444.2	13	4709.83	13	2584.93	13	1781.45	13	1359.10
14	24555.4	14	4645.69	14	2565.65	14	1772.27	14	1353.75
15	22918.8	15	4583.75	15	2546.64	15	1763.18	15	1348.45
16	21485.9	16	4523.44	16	2527.92	16	1754.19	16	1343.15
17	20222.1	17	4464.70	17	2509.47	17	1745.26	17	1337.65
18	19098.6	18	4407.46	18	2491.29	18	1736.48	18	1332.77
19	18093.4	19	4351.67	19	2473.37	19	1727.75	19	1327.63
20	17188.8	20	4297.28	20	2455.70	20	1719.12	20	1322.53
21	16370.2	21	4244.23	21	2438.29	21	1710.56	21	1317.46
22	15626.1	22	4192.47	22	2421.12	22	1702.10	22	1312.43
23	14946.7	23	4141.96	23	2404.19	23	1693.72	23	1307.45
24	14328.6	24	4092.66	24	2387.50	24	1685.42	24	1302.50
25	13751.0	25	4044.51	25	2371.04	25	1677.20	25	1297.58
26	13222.1	26	3997.49	26	2354.80	26	1669.06	26	1292.71
27	12732.4	27	3951.54	27	2338.78	27	1661.00	27	1287.87
28	12277.7	28	3906.54	28	2322.98	28	1653.01	28	1283.07
29	11854.3	29	3862.74	29	2307.39	29	1645.11	29	1278.30
30	11459.2	30	3819.83	30	2292.01	30	1637.28	30	1273.57
31	11089.6	31	3777.85	31	2276.84	31	1629.52	31	1268.87
32	10748.0	32	3736.79	32	2261.86	32	1621.84	32	1264.21
33	10417.5	33	3696.61	33	2247.08	33	1614.22	33	1259.58
34	10111.1	34	3657.29	34	2232.49	34	1606.68	34	1254.98
35	9822.18	35	3618.80	35	2218.09	35	1599.21	35	1250.42
36	9549.34	36	3581.10	36	2203.87	36	1591.81	36	1245.89
37	9291.29	37	3544.19	37	2189.84	37	1584.48	37	1241.40
38	9046.75	38	3508.02	38	2175.98	38	1577.21	38	1236.94
39	8814.78	39	3473.59	39	2162.30	39	1570.01	39	1232.51
40	8594.42	40	3437.87	40	2148.79	40	1562.88	40	1228.11
41	8384.80	41	3403.83	41	2135.44	41	1555.81	41	1223.74
42	8185.16	42	3370.46	42	2122.26	42	1548.79	42	1219.40
43	7994.81	43	3337.74	43	2109.24	43	1541.86	43	1215.80
44	7813.11	44	3305.65	44	2096.39	44	1534.98	44	1210.82
45	7639.49	45	3274.17	45	2083.68	45	1528.16	45	1206.57
46	7473.42	46	3243.29	46	2071.13	46	1521.40	46	1202.36
47	7314.41	47	3212.98	47	2058.73	47	1514.70	47	1198.17
48	7162.03	48	3183.23	48	2046.48	48	1508.06	48	1194.01
49	7015.87	49	3154.03	49	2034.37	49	1501.48	49	1189.88
50	6875.55	50	3125.86	50	2022.41	50	1494.95	50	1185.78
51	6740.74	51	3097.20	51	2010.59	51	1488.48	51	1181.71
52	6611.12	52	3069.65	52	1998.90	52	1482.07	52	1177.66
53	6486.88	53	3042.39	53	1987.35	53	1475.71	53	1173.65
54	6366.26	54	3015.71	54	1975.93	54	1469.41	54	1169.66
55	6250.51	55	2989.48	55	1964.64	55	1463.16	55	1165.70
56	6138.90	56	2963.71	56	1953.48	56	1456.96	56	1161.76
57	6031.20	57	2938.39	57	1942.44	57	1450.81	57	1157.85
58	5927.22	58	2913.49	58	1931.53	58	1444.72	58	1153.97
59	5826.76	59	2889.01	59	1920.75	59	1438.68	59	1150.11
60	5729.65	60	2864.93	60	1910.08	60	1432.69	60	1146.28

TABLE I.—RADII.

Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.
5° 0'	1146.28	6° 0'	955.37	7° 0'	818.64	8° 0'	716.34	9° 0'	636.78
1	1142.47	1	952.72	1	816.70	1	714.85	1	635.61
2	1138.69	2	950.09	2	814.76	2	713.37	2	634.44
3	1134.94	3	947.48	3	812.83	3	711.90	3	633.27
4	1131.21	4	944.88	4	810.92	4	710.43	4	632.10
5	1127.50	5	942.29	5	809.01	5	708.96	5	630.94
6	1123.82	6	939.72	6	807.11	6	707.51	6	629.79
7	1120.16	7	937.16	7	805.22	7	706.05	7	628.64
8	1116.52	8	934.62	8	803.34	8	704.60	8	627.49
9	1112.91	9	932.09	9	801.47	9	703.16	9	626.35
10	1109.33	10	929.57	10	799.61	10	701.73	10	625.21
11	1105.76	11	927.07	11	797.75	11	700.30	11	624.08
12	1102.22	12	924.58	12	795.91	12	698.88	12	622.95
13	1098.70	13	922.10	13	794.07	13	697.46	13	621.82
14	1095.20	14	919.64	14	792.24	14	696.05	14	620.70
15	1091.73	15	917.19	15	790.42	15	694.65	15	619.58
16	1088.28	16	914.75	16	788.61	16	693.24	16	618.47
17	1084.85	17	912.33	17	786.80	17	691.85	17	617.36
18	1081.44	18	909.92	18	785.01	18	690.46	18	616.25
19	1078.05	19	907.52	19	783.22	19	689.08	19	615.15
20	1074.68	20	905.13	20	781.44	20	687.70	20	614.05
21	1071.34	21	902.76	21	779.67	21	686.33	21	612.96
22	1068.01	22	900.40	22	777.91	22	684.96	22	611.87
23	1064.71	23	898.05	23	776.15	23	683.60	23	610.78
24	1061.43	24	895.71	24	774.40	24	682.25	24	609.70
25	1058.16	25	893.39	25	772.66	25	680.89	25	608.62
26	1054.92	26	891.08	26	770.93	26	679.55	26	607.55
27	1051.70	27	888.78	27	769.21	27	678.21	27	606.48
28	1048.48	28	886.49	28	767.49	28	676.88	28	605.41
29	1045.31	29	884.21	29	765.78	29	675.54	29	604.35
30	1042.14	30	881.95	30	764.08	30	674.22	30	603.29
31	1039.00	31	879.69	31	762.39	31	672.90	31	602.23
32	1035.87	32	877.45	32	760.70	32	671.59	32	601.18
33	1032.76	33	875.22	33	759.02	33	670.28	33	600.13
34	1029.67	34	873.00	34	757.35	34	668.98	34	599.09
35	1026.60	35	870.80	35	755.69	35	667.68	35	598.04
36	1023.55	36	868.60	36	754.03	36	666.39	36	597.01
37	1020.51	37	866.41	37	752.38	37	665.10	37	595.97
38	1017.49	38	864.24	38	750.74	38	663.82	38	594.94
39	1014.50	39	862.08	39	749.10	39	662.54	39	593.91
40	1011.51	40	859.92	40	747.48	40	661.26	40	592.89
41	1008.55	41	857.78	41	745.86	41	659.99	41	591.87
42	1005.60	42	855.65	42	744.24	42	658.73	42	590.85
43	1002.67	43	853.53	43	742.63	43	657.47	43	589.84
44	999.76	44	851.42	44	741.03	44	656.22	44	588.83
45	996.87	45	849.32	45	739.44	45	654.97	45	587.83
46	993.99	46	847.23	46	737.86	46	653.72	46	586.82
47	991.13	47	845.15	47	736.28	47	652.48	47	585.83
48	988.28	48	843.08	48	734.70	48	651.25	48	584.83
49	985.45	49	841.02	49	733.14	49	650.02	49	583.84
50	982.64	50	838.97	50	731.59	50	648.79	50	582.85
51	979.84	51	836.93	51	730.03	51	647.57	51	581.86
52	977.06	52	834.90	52	728.48	52	646.35	52	580.88
53	974.29	53	832.89	53	726.94	53	645.14	53	579.90
54	971.54	54	830.88	54	725.41	54	643.94	54	578.92
55	968.81	55	828.88	55	723.89	55	642.73	55	577.95
56	966.09	56	826.89	56	722.36	56	641.53	56	576.98
57	963.39	57	824.91	57	720.85	57	640.34	57	576.02
58	960.70	58	822.93	58	719.34	58	639.15	58	575.06
59	958.03	59	820.97	59	717.84	59	637.96	59	574.10
60	955.37	60	819.02	60	716.34	60	636.78	60	573.14

TABLE I.—RADII.

Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.	Deg.	Radius.
10° 0'	573.14	12° 0'	477.68	14° 0'	409.32	16° 0'	358.17	18° 0'	318.81
2	571.24	2	476.36	2	408.35	2	357.43	2	317.86
4	569.35	4	475.05	4	407.38	4	356.69	4	317.22
6	567.47	6	473.74	6	406.42	6	355.95	6	316.63
8	565.60	8	472.44	8	405.46	8	355.21	8	316.05
10	563.75	10	471.15	10	404.51	10	354.48	10	315.47
12	561.91	12	469.86	12	403.56	12	353.75	12	314.89
14	560.08	14	468.58	14	402.61	14	353.03	14	314.32
16	558.26	16	467.31	16	401.67	16	352.30	16	313.75
18	556.45	18	466.04	18	400.74	18	351.58	18	313.18
20	554.66	20	464.78	20	399.80	20	350.86	20	312.61
22	552.88	22	463.53	22	398.88	22	350.15	22	312.04
24	551.11	24	462.29	24	397.95	24	349.44	24	311.47
26	549.35	26	461.05	26	397.03	26	348.72	26	310.91
28	547.60	28	459.82	28	396.13	28	348.02	28	310.35
30	545.87	30	458.59	30	395.21	30	347.32	30	309.79
32	544.14	32	457.38	32	394.30	32	346.62	32	309.23
34	542.42	34	456.16	34	393.40	34	345.93	34	308.68
36	540.72	36	454.96	36	392.50	36	345.23	36	308.13
38	539.03	38	453.76	38	391.61	38	344.54	38	307.58
40	537.34	40	452.57	40	390.72	40	343.85	40	307.03
42	535.67	42	451.38	42	389.83	42	343.16	42	306.48
44	534.01	44	450.20	44	388.95	44	342.48	44	305.93
46	532.36	46	449.02	46	388.07	46	341.80	46	305.39
48	530.71	48	447.86	48	387.20	48	341.12	48	304.85
50	529.08	50	446.69	50	386.33	50	340.45	50	304.31
52	527.46	52	445.54	52	385.47	52	339.78	52	303.77
54	525.85	54	444.39	54	384.60	54	339.11	54	303.24
56	524.25	56	443.24	56	383.75	56	338.44	56	302.70
58	522.65	58	442.11	58	382.89	58	337.77	58	302.17
11° 0'	521.07	13° 0'	440.97	15° 0'	382.04	17° 0'	337.11	19° 0'	301.64
2	519.50	2	439.85	2	381.19	2	336.45	2	301.12
4	517.93	4	438.73	4	380.35	4	335.80	4	300.59
6	516.38	6	437.61	6	379.51	6	335.14	6	300.07
8	514.84	8	436.50	8	378.68	8	334.49	8	299.54
10	513.30	10	435.40	10	377.84	10	333.84	10	299.02
12	511.77	12	434.30	12	377.02	12	333.19	12	298.50
14	510.26	14	433.21	14	376.19	14	332.55	14	297.99
16	508.75	16	432.12	16	375.37	16	331.91	16	297.47
18	507.25	18	431.04	18	374.55	18	331.27	18	296.96
20	505.76	20	429.96	20	373.74	20	330.63	20	296.45
22	504.28	22	428.98	22	372.93	22	330.00	22	295.94
24	502.80	24	427.82	24	372.12	24	329.37	24	295.43
26	501.34	26	426.76	26	371.32	26	328.74	26	294.92
28	499.88	28	425.71	28	370.52	28	328.11	28	294.42
30	498.43	30	424.66	30	369.72	30	327.48	30	293.91
32	496.99	32	423.61	32	368.93	32	326.86	32	293.41
34	495.56	34	422.57	34	368.14	34	326.24	34	292.91
36	494.14	36	421.54	36	367.35	36	325.62	36	292.41
38	492.73	38	420.51	38	366.57	38	325.01	38	291.92
40	491.32	40	419.49	40	365.79	40	324.40	40	291.42
42	489.92	42	418.47	42	365.01	42	323.79	42	290.93
44	488.53	44	417.45	44	364.24	44	323.18	44	290.44
46	487.15	46	416.44	46	363.47	46	322.57	46	289.95
48	485.77	48	415.44	48	362.70	48	321.97	48	289.46
50	484.40	50	414.44	50	361.94	50	321.37	50	288.98
52	483.05	52	413.44	52	361.18	52	320.77	52	288.49
54	481.69	54	412.45	54	360.42	54	320.17	54	288.01
56	480.35	56	411.47	56	359.67	56	319.57	56	287.53
58	479.01	58	410.49	58	358.92	58	318.98	58	287.05
60	477.68	60	409.51	60	358.17	60	318.39	60	286.57

TABLE II.—TANGENTS AND EXTERNALS TO A 1° CURVE.

Angle. α	Tan- gent. T.	Exter- nal. E.	Angle. α	Tan- gent. T.	Exter- nal. E.	Angle. α	Tan- gent. T.	Exter- nal. E.
1°	50.00	.218	11	551.70	26.500	21°	1061.9	97.577
10'	58.34	.297	10'	560.11	27.313	10'	1070.6	99.155
20	66.67	.388	20	568.53	28.137	20	1079.2	100.75
30	75.01	.491	30	576.95	28.974	30	1087.8	102.35
40	83.34	.606	40	585.36	29.824	40	1096.4	103.97
50	91.68	.738	50	593.79	30.686	50	1105.1	105.60
2	100.01	.878	12	602.21	31.561	22	1113.7	107.24
10	108.35	1.024	10	610.64	32.447	10	1122.4	108.90
20	116.68	1.188	20	619.07	33.347	20	1131.0	110.57
30	125.02	1.364	30	627.50	34.259	30	1139.7	112.25
40	133.36	1.552	40	635.93	35.183	40	1148.4	113.95
50	141.70	1.752	50	644.37	36.120	50	1157.0	115.66
3	150.04	1.964	13	652.81	37.070	23	1165.7	117.38
10	158.38	2.188	10	661.25	38.031	10	1174.4	119.12
20	166.72	2.425	20	669.70	39.006	20	1183.1	120.87
30	175.06	2.674	30	678.15	39.993	30	1191.8	122.63
40	183.40	2.934	40	686.60	40.992	40	1200.5	124.41
50	191.74	3.207	50	695.06	42.004	50	1209.2	126.20
4	200.08	3.492	14	703.51	43.029	24	1217.9	128.00
10	208.43	3.790	10	711.97	44.066	10	1226.6	129.82
20	216.77	4.099	20	720.44	45.116	20	1235.3	131.65
30	225.12	4.421	30	728.90	46.178	30	1244.0	133.50
40	233.47	4.755	40	737.37	47.253	40	1252.8	135.35
50	241.81	5.100	50	745.85	48.341	50	1261.5	137.23
5	250.16	5.459	15	754.32	49.441	25	1270.2	139.11
10	258.51	5.829	10	762.80	50.554	10	1279.0	141.01
20	266.86	6.211	20	771.29	51.679	20	1287.7	142.93
30	275.21	6.606	30	779.77	52.818	30	1296.5	144.85
40	283.57	7.013	40	788.26	53.969	40	1305.3	146.79
50	291.92	7.432	50	796.75	55.132	50	1314.0	148.75
6	300.28	7.863	16	805.25	56.309	26	1322.8	150.71
10	308.64	8.307	10	813.75	57.498	10	1331.6	152.69
20	316.99	8.762	20	822.25	58.699	20	1340.4	154.69
30	325.35	9.230	30	830.76	59.914	30	1349.2	156.70
40	333.71	9.710	40	839.27	61.141	40	1358.0	158.72
50	342.08	10.202	50	847.78	62.381	50	1366.8	160.76
7	350.44	10.707	17	856.30	63.634	27	1375.6	162.81
10	358.81	11.224	10	864.82	64.900	10	1384.4	164.86
20	367.17	11.753	20	873.35	66.178	20	1393.2	166.96
30	375.54	12.294	30	881.88	67.470	30	1402.0	169.04
40	383.91	12.847	40	890.41	68.774	40	1410.9	171.15
50	392.28	13.413	50	898.95	70.091	50	1419.7	173.27
8	400.66	13.991	18	907.49	71.421	28	1428.6	175.41
10	409.03	14.582	10	916.03	72.764	10	1437.4	177.55
20	417.41	15.184	20	924.58	74.119	20	1446.3	179.72
30	425.79	15.799	30	933.13	75.488	30	1455.1	181.89
40	434.17	16.426	40	941.69	76.869	40	1464.0	184.08
50	442.55	17.065	50	950.25	78.264	50	1472.9	186.29
9	450.93	17.717	19	958.81	79.671	29	1481.8	188.51
10	459.32	18.381	10	967.38	81.092	10	1490.7	190.74
20	467.71	19.058	20	975.96	82.525	20	1499.6	192.99
30	476.10	19.746	30	984.53	83.972	30	1508.5	195.25
40	484.49	20.447	40	993.12	85.431	40	1517.4	197.53
50	492.88	21.161	50	1001.7	86.904	50	1526.3	199.83
10	501.28	21.887	20	1010.3	88.389	30	1535.3	202.12
10	509.68	22.624	10	1018.9	89.888	10	1544.2	204.44
20	518.08	23.373	20	1027.5	91.399	20	1553.1	206.77
30	526.48	24.138	30	1036.1	92.924	30	1562.1	209.12
40	534.89	24.913	40	1044.7	94.462	40	1571.0	211.48
50	543.29	25.700	50	1053.3	96.013	50	1580.0	213.86

TABLE II.—TANGENTS AND EXTERNALS TO A 1° CURVE.

Angle. α	Tan- gent. T.	Exter- nal. E.	Angle. α	Tan- gent. T.	Exter- nal. E.	Angle. α	Tan- gent. T.	Exter- nal. E.
31°	1589.0	216.25	41°	2142.2	387.88	51°	2732.9	618.39
10	1598.0	218.66	10'	2151.7	390.71	10'	2743.1	622.81
20	1606.9	221.08	20	2161.2	394.06	20	2753.4	627.24
30	1615.9	223.51	30	2170.8	397.43	30	2763.7	631.69
40	1624.9	225.96	40	2180.3	400.82	40	2773.9	636.17
50	1633.9	228.42	50	2189.9	404.22	50	2784.2	640.66
32	1643.0	230.90	42	2199.4	407.64	52	2794.5	645.17
10	1652.0	233.39	10	2209.0	411.07	10	2804.9	649.70
20	1661.0	235.90	20	2218.6	414.52	20	2815.2	654.25
30	1670.0	238.43	30	2228.1	417.99	30	2825.6	658.83
40	1679.1	240.96	40	2237.7	421.48	40	2835.9	663.42
50	1688.1	243.52	50	2247.3	424.98	50	2846.3	668.03
33	1697.2	246.06	43	2257.0	428.50	53	2856.7	672.66
10	1706.3	248.66	10	2266.6	432.04	10	2867.1	677.32
20	1715.3	251.26	20	2276.2	435.59	20	2877.5	681.99
30	1724.4	253.87	30	2285.9	439.16	30	2888.0	686.68
40	1733.5	256.50	40	2295.6	442.75	40	2898.4	691.40
50	1742.6	259.14	50	2305.2	446.35	50	2908.9	696.13
34	1751.7	261.80	44	2314.9	449.98	54	2919.4	700.89
10	1760.8	264.47	10	2324.6	453.62	10	2929.9	705.66
20	1770.0	267.16	20	2334.3	457.27	20	2940.4	710.46
30	1779.1	269.86	30	2344.1	460.95	30	2951.0	715.28
40	1788.2	272.58	40	2353.8	464.64	40	2961.5	720.11
50	1797.4	275.31	50	2363.5	468.35	50	2972.1	724.97
35	1806.6	278.05	45	2373.3	472.08	55	2982.7	729.85
10	1815.7	280.82	10	2383.1	475.82	10	2993.3	734.76
20	1824.9	283.60	20	2392.8	479.59	20	3003.9	739.68
30	1834.1	286.39	30	2402.6	483.37	30	3014.5	744.62
40	1843.3	289.20	40	2412.4	487.17	40	3025.2	749.59
50	1852.5	292.02	50	2422.3	490.98	50	3035.8	754.57
36	1861.7	294.86	46	2432.1	494.82	56	3046.5	759.58
10	1870.9	297.72	10	2441.9	498.67	10	3057.2	764.61
20	1880.1	300.59	20	2451.8	502.54	20	3067.9	769.66
30	1889.4	303.47	30	2461.7	506.42	30	3078.7	774.73
40	1898.6	306.37	40	2471.5	510.33	40	3089.4	779.83
50	1907.9	309.29	50	2481.4	514.25	50	3100.2	784.94
37	1917.1	312.22	47	2491.3	518.20	57	3110.9	790.08
10	1926.4	315.17	10	2501.2	522.16	10	3121.7	795.24
20	1935.7	318.13	20	2511.2	526.13	20	3132.6	800.42
30	1945.0	321.11	30	2521.1	530.13	30	3143.4	805.62
40	1954.3	324.11	40	2531.1	534.15	40	3154.2	810.85
50	1963.6	327.12	50	2541.0	538.18	50	3165.1	816.10
38	1972.9	330.15	48	2551.0	542.23	58	3176.0	821.37
10	1982.2	333.19	10	2561.0	546.30	10	3186.9	826.66
20	1991.5	336.25	20	2571.0	550.39	20	3197.8	831.98
30	2000.9	339.32	30	2581.0	554.50	30	3208.8	837.31
40	2010.2	342.41	40	2591.1	558.63	40	3219.7	842.67
50	2019.6	345.52	50	2601.1	562.77	50	3230.7	848.06
39	2029.0	348.64	49	2611.2	566.94	59	3241.7	853.46
10	2038.4	351.78	10	2621.2	571.12	10	3252.7	858.89
20	2047.8	354.94	20	2631.3	575.32	20	3263.7	864.34
30	2057.2	358.11	30	2641.4	579.54	30	3274.8	869.82
40	2066.6	361.29	40	2651.5	583.78	40	3285.8	875.32
50	2076.0	364.50	50	2661.6	588.04	50	3296.9	880.84
40	2085.4	367.72	50	2671.8	592.32	60	3308.0	886.38
10	2094.9	370.95	10	2681.9	596.62	10	3319.1	891.95
20	2104.3	374.20	20	2692.1	600.93	20	3330.3	897.54
30	2113.8	377.47	30	2702.3	605.27	30	3341.4	903.15
40	2123.3	380.76	40	2712.5	609.62	40	3352.6	908.79
50	2132.7	384.06	50	2722.7	614.00	50	3363.8	914.45

TABLE II.—TANGENTS AND EXTERNALS TO A 1° CURVE.

Angle. α	Tan- gent. T.	Exter- nal. E.	Angle. α	Tan- gent. T.	Exter- nal. E.	Angle. α	Tan- gent. T.	Exter- nal. E.
61°	3375.0	920.14	71°	4066.9	1308.2	81°	4898.6	1805.3
10'	3386.8	925.85	10'	4099.5	1315.6	10'	4908.0	1814.7
20	3397.5	931.58	20	4112.1	1322.9	20	4922.5	1824.1
30	3406.8	937.34	30	4124.8	1330.3	30	4937.0	1833.6
40	3420.1	943.12	40	4137.4	1337.7	40	4951.5	1843.1
50	3431.4	948.92	50	4150.1	1345.1	50	4966.1	1852.6
62	3442.7	954.75	72	4162.8	1352.6	82	4980.7	1862.2
10	3454.1	960.60	10	4175.6	1360.1	10	4995.4	1871.8
20	3465.4	966.48	20	4188.5	1367.6	20	5010.0	1881.5
30	3476.8	972.38	30	4201.2	1375.2	30	5024.8	1891.2
40	3488.3	978.31	40	4214.0	1382.8	40	5039.5	1900.9
50	3499.7	984.27	50	4226.8	1390.4	50	5054.3	1910.7
63	3511.1	990.24	73	4239.7	1398.0	83	5069.2	1920.5
10	3522.6	996.24	10	4252.6	1405.7	10	5084.0	1930.4
20	3534.1	1002.3	20	4265.6	1413.5	20	5099.0	1940.3
30	3545.6	1008.3	30	4278.5	1421.2	30	5113.9	1950.3
40	3557.2	1014.4	40	4291.5	1429.0	40	5128.9	1960.2
50	3568.7	1020.5	50	4304.6	1436.8	50	5143.9	1970.3
64	3580.3	1026.6	74	4317.6	1444.6	84	5159.0	1980.4
10	3591.9	1032.8	10	4330.7	1452.5	10	5174.1	1990.5
20	3603.5	1039.0	20	4343.8	1460.4	20	5189.3	2000.6
30	3615.1	1045.2	30	4356.9	1468.4	30	5204.4	2010.8
40	3626.8	1051.4	40	4370.1	1476.4	40	5219.7	2021.1
50	3638.5	1057.7	50	4383.3	1484.4	50	5234.9	2031.4
65	3650.2	1063.9	75	4396.5	1492.4	85	5250.3	2041.7
10	3661.9	1070.2	10	4409.8	1500.5	10	5265.6	2052.1
20	3673.7	1076.6	20	4423.1	1508.6	20	5281.0	2062.5
30	3685.4	1082.9	30	4436.4	1516.7	30	5296.4	2073.0
40	3697.2	1089.3	40	4449.7	1524.9	40	5311.9	2083.5
50	3709.0	1095.7	50	4463.1	1533.1	50	5327.4	2094.1
66	3720.9	1102.2	76	4476.5	1541.4	86	5343.0	2104.7
10	3732.7	1108.6	10	4489.9	1549.7	10	5358.6	2115.3
20	3744.6	1115.1	20	4503.4	1558.0	20	5374.2	2126.0
30	3756.5	1121.7	30	4516.9	1566.3	30	5389.9	2136.7
40	3768.5	1128.2	40	4530.4	1574.7	40	5405.6	2147.5
50	3780.4	1134.8	50	4544.0	1583.1	50	5421.4	2158.4
67	3792.4	1141.4	77	4557.6	1591.6	87	5437.2	2169.2
10	3804.4	1148.0	10	4571.2	1600.1	10	5453.1	2180.2
20	3816.4	1154.7	20	4584.8	1608.6	20	5469.0	2191.1
30	3828.4	1161.3	30	4598.5	1617.1	30	5484.9	2202.2
40	3840.5	1168.1	40	4612.2	1625.7	40	5500.9	2213.2
50	3852.6	1174.8	50	4626.0	1634.4	50	5517.0	2224.3
68	3864.7	1181.6	78	4639.8	1643.0	88	5533.1	2235.5
10	3876.8	1188.4	10	4653.6	1651.7	10	5549.2	2246.7
20	3889.0	1195.2	20	4667.4	1660.5	20	5565.4	2258.0
30	3901.2	1202.0	30	4681.3	1669.2	30	5581.6	2269.3
40	3913.4	1208.9	40	4695.2	1678.1	40	5597.8	2280.6
50	3925.6	1215.8	50	4709.2	1686.9	50	5614.2	2292.0
69	3937.9	1222.7	79	4723.2	1695.8	89	5630.5	2303.5
10	3950.2	1229.7	10	4737.2	1704.7	10	5646.9	2315.0
20	3962.5	1236.7	20	4751.2	1713.7	20	5663.4	2326.6
30	3974.8	1243.7	30	4765.3	1722.7	30	5679.9	2338.2
40	3987.2	1250.8	40	4779.4	1731.7	40	5696.4	2349.8
50	3999.5	1257.9	50	4793.6	1740.8	50	5713.0	2361.5
70	4011.9	1265.0	80	4807.7	1749.9	90	5729.7	2373.8
10	4024.4	1272.1	10	4822.0	1759.0	10	5746.3	2385.1
20	4036.8	1279.3	20	4836.2	1768.2	20	5763.1	2397.0
30	4049.3	1286.5	30	4850.5	1777.4	30	5779.9	2408.9
40	4061.8	1293.6	40	4864.8	1786.7	40	5796.7	2420.9
50	4074.4	1300.9	50	4879.2	1796.0	50	5813.6	2432.9

TABLE II.—TANGENTS AND EXTERNALS TO A 1° CURVE.

Angle. α	Tan- gent. T.	Ex- ternal. E.	Angle. α	Tan- gent. T.	Ex- ternal. E.	Angle. α	Tan- gent. T.	Ex- ternal. E.
91°	5890.5	2444.9	97	6476.2	2917.3	103	7203.2	3474.4
10'	5847.5	2457.1	10	6495.2	2931.6	10	7224.7	3491.3
20	5864.6	2469.3	20	6514.3	2945.9	20	7246.3	3508.2
30	5881.7	2481.5	30	6533.4	2960.3	30	7268.0	3525.2
40	5898.8	2493.8	40	6552.6	2974.7	40	7289.8	3542.4
50	5916.0	2506.1	50	6571.9	2989.2	50	7311.7	3559.6
92	5933.2	2518.5	98	6591.2	3003.8	104	7333.6	3576.8
10	5950.5	2531.0	10	6610.6	3018.4	10	7355.6	3594.2
20	5967.9	2543.5	20	6630.1	3033.1	20	7377.8	3611.7
30	5985.3	2556.0	30	6649.6	3047.9	30	7399.9	3629.2
40	6002.7	2568.6	40	6669.2	3062.8	40	7422.2	3646.8
50	6020.2	2581.3	50	6688.8	3077.7	50	7444.6	3664.5
93	6037.8	2594.0	99	6708.6	3092.7	105	7467.0	3682.3
10	6055.4	2606.8	10	6728.4	3107.7	10	7489.6	3700.2
20	6073.1	2619.7	20	6748.2	3122.9	20	7512.2	3718.2
30	6090.8	2632.6	30	6768.1	3138.1	30	7534.9	3736.2
40	6108.6	2645.5	40	6788.1	3153.3	40	7557.7	3754.4
50	6126.4	2658.5	50	6808.2	3168.7	50	7580.5	3772.6
94	6144.3	2671.6	100	6828.3	3184.1	106	7603.5	3791.0
10	6162.2	2684.7	10	6848.5	3199.6	10	7626.6	3809.4
20	6180.2	2697.9	20	6868.8	3215.1	20	7649.7	3827.9
30	6198.3	2711.2	30	6889.2	3230.8	30	7672.9	3846.5
40	6216.4	2724.5	40	6909.6	3246.5	40	7696.3	3865.2
50	6234.6	2737.9	50	6930.1	3262.3	50	7719.7	3884.0
95	6252.8	2751.3	101°	6950.6	3278.1	107	7743.2	3902.9
10	6271.1	2764.8	10'	6971.3	3294.1	10	7766.8	3921.9
20	6289.4	2778.3	20	6992.0	3310.1	20	7790.5	3940.9
30	6307.9	2792.0	30	7012.7	3326.1	30	7814.3	3960.1
40	6326.3	2805.6	40	7033.6	3342.3	40	7838.1	3979.4
50	6344.8	2819.4	50	7054.5	3358.5	50	7862.1	3998.7
96	6363.4	2833.2	102	7075.5	3374.9	108	7886.2	4018.2
10	6382.1	2847.0	10	7096.6	3391.2	10	7910.4	4037.8
20	6400.8	2861.0	20	7117.8	3407.7	20	7934.6	4057.4
30	6419.5	2875.0	30	7139.0	3424.3	30	7959.0	4077.2
40	6438.4	2889.0	40	7160.3	3440.9	40	7983.5	4097.1
50	6457.3	2903.1	50	7181.7	3457.6	50	8008.0	4117.0

CORRECTIONS FOR TANGENTS AND EXTERNALS.

FOR TANGENTS, ADD							FOR EXTERNALS, ADD						
Ang α	5° Cur.	10° Cur.	15° Cur.	20° Cur.	25° Cur.	30° Cur.	Ang α	5° Cur.	10° Cur.	15° Cur.	20° Cur.	25° Cur.	30° Cur.
10°	.03	.06	.09	.13	.16	.19	10°	.001	.003	.004	.006	.007	.008
20	.06	.13	.19	.26	.32	.39	20	.006	.011	.017	.022	.028	.034
30	.10	.19	.29	.39	.49	.59	30	.013	.025	.038	.051	.065	.078
40	.13	.26	.40	.53	.67	.80	40	.023	.046	.070	.093	.117	.141
50	.17	.34	.51	.68	.85	1.02	50	.037	.075	.116	.151	.189	.227
60	.21	.42	.63	.84	1.05	1.27	60	.056	.112	.168	.225	.283	.340
70	.25	.51	.76	1.02	1.28	1.54	70	.080	.159	.240	.321	.403	.485
80	.30	.61	.91	1.22	1.53	1.84	80	.110	.220	.332	.445	.558	.671
90	.36	.72	1.09	1.45	1.83	2.20	90	.149	.299	.450	.603	.756	.910
100	.43	.86	1.30	1.74	2.18	2.62	100	.200	.401	.604	.809	1.015	1.221
110	.51	1.03	1.56	2.08	2.61	3.14	110	.263	.536	.806	1.082	1.355	1.633
120	.62	1.25	1.93	2.52	3.16	3.81	120	.360	.721	1.066	1.456	1.825	2.197

TABLE III. TANGENTIAL OFFSETS 100 FT. ALONG THE CURVE.

Deg. of Curve.	0'	10'	20'	30'	40'	50'
0°	0.000	0.145	0.291	0.436	0.582	0.727
1°	0.873	1.018	1.164	1.309	1.454	1.600
2°	1.745	1.891	2.036	2.181	2.327	2.472
3°	2.618	2.763	2.908	3.054	3.199	3.345
4°	3.490	3.635	3.781	3.926	4.071	4.217
5°	4.362	4.507	4.653	4.798	4.943	5.088
6°	5.234	5.379	5.524	5.669	5.814	5.960
7°	6.105	6.250	6.395	6.540	6.685	6.831
8°	6.976	7.121	7.266	7.411	7.556	7.701
9°	7.846	7.991	8.136	8.281	8.426	8.571
10°	8.716	8.860	9.005	9.150	9.295	9.440
11°	9.585	9.729	9.874	10.019	10.164	10.308
12°	10.453	10.597	10.742	10.887	11.031	11.176
13°	11.320	11.465	11.609	11.754	11.898	12.043
14°	12.187	12.331	12.476	12.620	12.764	12.908
15°	13.053	13.197	13.341	13.485	13.629	13.773
16°	13.917	14.061	14.205	14.349	14.493	14.637
17°	14.781	14.925	15.069	15.212	15.356	15.500
18°	15.643	15.787	15.931	16.074	16.218	16.361
19°	16.505	16.648	16.792	16.935	17.078	17.222
20°	17.365	17.508	17.651	17.794	17.937	18.081
21°	18.224	18.367	18.509	18.652	18.795	18.938
22°	19.081	19.224	19.366	19.509	19.652	19.794
23°	19.937	20.079	20.222	20.364	20.507	20.649
24°	20.791	20.933	21.076	21.218	21.360	21.502

TABLE IV.—MID-ORDINATES TO A 100-FT. CHORD.

Deg. of Curve.	0	1	2	3	4	5	6	7	8	9
0°	0.000	0.218	0.436	0.655	0.873	1.091	1.309	1.528	1.746	1.965
10°	2.183	2.402	2.620	2.839	3.058	3.277	3.496	3.716	3.935	4.155
20°	4.374	4.594	4.814	5.035	5.255	5.476	5.697	5.918	6.139	6.360

Note.—As an example illustrating the use of Table II, suppose we require the value of T for a 5° curve, where $I = 40^\circ 20'$. Then

$$T = \frac{2104.3}{5} + .13 = 420.99.$$

TABLE V.—LONG CHORDS.

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
0° 10'	100.000	200.000	299.999	399.998	499.996	599.993
20	.000	199.999	299.997	399.992	499.983	599.970
30	.000	199.998	299.992	399.981	499.962	599.933
40	.001	199.997	299.986	399.966	499.932	599.882
50	.001	199.995	299.979	399.947	499.894	599.815
1	100.001	199.992	299.970	399.924	499.848	599.733
10	.002	199.990	299.959	399.896	499.793	599.637
20	.002	199.986	299.946	399.865	499.729	599.526
30	.003	199.983	299.932	399.829	499.657	599.401
40	.003	199.979	299.915	399.789	499.577	599.260
50	.004	199.974	299.898	399.744	499.488	599.105
2	100.005	199.970	299.878	399.695	499.391	598.934
10	.006	199.964	299.857	399.643	499.285	598.750
20	.007	199.959	299.834	399.586	499.171	598.550
30	.008	199.952	299.810	399.524	499.049	598.336
40	.009	199.946	299.783	399.459	498.918	598.106
50	.010	199.939	299.756	399.389	498.778	597.862
3	100.011	199.931	299.726	399.315	498.630	597.604
10	.013	199.924	299.695	399.237	498.474	597.331
20	.014	199.915	299.662	399.154	498.309	597.043
30	.015	199.907	299.627	399.068	498.136	596.740
40	.017	199.898	299.591	398.977	497.955	596.423
50	.019	199.888	299.553	398.882	497.765	596.091
4	100.020	199.878	299.513	398.782	497.566	595.744
10	.022	199.868	299.471	398.679	497.360	595.383
20	.024	199.857	299.428	398.571	497.145	595.007
30	.026	199.846	299.383	398.459	496.921	594.617
40	.028	199.834	299.337	398.343	496.689	594.212
50	.030	199.822	299.289	398.223	496.449	593.792
5	100.032	199.810	299.239	398.099	496.201	593.358
10	.034	199.797	299.187	397.970	495.944	592.909
20	.036	199.783	299.134	397.837	495.678	592.446
30	.038	199.770	299.079	397.700	495.405	591.968
40	.041	199.756	299.023	397.559	495.123	591.476
50	.043	199.741	298.964	397.413	494.832	590.970
6	100.046	199.726	298.904	397.264	494.534	590.449
10	.048	199.710	298.843	397.110	494.227	589.913
20	.051	199.695	298.779	396.952	493.912	589.364
30	.054	199.678	298.714	396.790	493.588	588.800
40	.056	199.662	298.648	396.623	493.257	588.221
50	.059	199.644	298.579	396.453	492.917	587.628
7	100.062	199.627	298.509	396.273	492.568	587.021
10	.065	199.609	298.438	396.099	492.212	586.400
20	.068	199.591	298.364	395.916	491.847	585.765
30	.071	199.572	298.289	395.729	491.474	585.115
40	.075	199.553	298.212	395.538	491.093	584.451
50	.078	199.533	298.134	395.342	490.704	583.773
8	100.061	199.513	298.054	395.142	490.306	583.081
10	.085	199.492	297.972	394.938	489.900	582.375
20	.088	199.471	297.888	394.731	489.486	581.654
30	.092	199.450	297.803	394.518	489.064	580.920
40	.096	199.428	297.716	394.302	488.634	580.172
50	.099	199.406	297.628	394.082	488.196	579.409
9	100.103	199.383	297.538	393.857	487.749	578.633
10	.107	199.360	297.446	393.629	487.294	577.843
20	.111	199.337	297.352	393.396	486.832	577.039
30	.115	199.313	297.257	393.159	486.361	576.222
40	.119	199.289	297.160	392.918	485.882	575.390
50	.123	199.264	297.062	392.673	485.395	574.545
10	100.127	199.239	296.962	392.424	484.900	573.686

TABLE V.—LONG CHORDS.

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
10° 10'	100.181	199.213	296.860	392.171	484.397	572.813
20	.186	199.187	296.756	391.914	483.886	571.996
30	.140	199.161	296.651	391.652	483.367	571.027
40	.145	199.134	296.544	391.387	482.840	570.113
50	.149	199.107	296.436	391.117	482.305	569.166
11	100.154	199.079	296.325	390.843	481.762	568.245
10	.158	199.051	296.214	390.565	481.211	567.292
20	.163	199.023	296.100	390.284	480.653	566.324
30	.168	198.994	295.985	389.998	480.086	565.343
40	.173	198.964	295.868	389.708	479.511	564.349
50	.178	198.935	295.750	389.414	478.929	563.341
12	100.183	198.904	295.629	389.116	478.338	562.321
10	.188	198.874	295.508	388.814	477.740	561.287
20	.193	198.843	295.384	388.508	477.135	560.240
30	.199	198.811	295.259	388.197	476.521	559.180
40	.204	198.779	295.132	387.883	475.899	558.107
50	.209	198.747	295.004	387.565	475.270	557.020
13	100.215	198.714	294.874	387.243	474.633	555.921
10	.220	198.681	294.742	386.916	473.988	554.809
20	.226	198.648	294.609	386.586	473.336	553.684
30	.232	198.614	294.474	386.252	472.675	552.546
40	.237	198.579	294.337	385.914	472.007	551.395
50	.243	198.544	294.199	385.572	471.332	550.232
14	100.249	198.509	294.059	385.225	470.649	549.056
10	.255	198.474	293.918	384.875	469.958	547.867
20	.261	198.437	293.774	384.521	469.260	546.666
30	.267	198.401	293.629	384.163	468.554	545.452
40	.274	198.364	293.483	383.801	467.840	544.226
50	.280	198.327	293.335	383.435	467.119	542.987
15	100.286	198.289	293.185	383.065	466.390	541.736
10	.292	198.251	293.034	382.691	465.654	540.472
20	.299	198.212	292.881	382.313	464.911	539.196
30	.306	198.173	292.726	381.931	464.160	537.908
40	.312	198.134	292.570	381.546	463.401	536.608
50	.319	198.094	292.412	381.156	462.635	535.296
16	100.326	198.054	292.252	380.763	461.862	533.972
10	.333	198.013	292.091	380.365	461.081	532.635
20	.339	197.973	291.928	379.964	460.293	531.287
30	.346	197.930	291.764	379.559	459.498	529.927
40	.353	197.888	291.598	379.150	458.695	528.555
50	.361	197.846	291.430	378.737	457.886	527.171
17	100.368	197.803	291.261	378.320	457.069	525.776
10	.375	197.760	291.090	377.900	456.244	524.369
20	.382	197.716	290.918	377.475	455.413	522.950
30	.390	197.672	290.743	377.047	454.574	521.519
40	.397	197.628	290.568	376.615	453.728	520.073
50	.405	197.583	290.390	376.179	452.875	518.625
18	100.412	197.538	290.211	375.739	452.015	517.160
10	.420	197.492	290.031	375.295	451.147	515.685
20	.428	197.446	289.849	374.848	450.273	514.198
30	.436	197.399	289.665	374.397	449.392	512.699
40	.444	197.352	289.479	373.942	448.504	511.190
50	.452	197.305	289.292	373.483	447.608	509.670
19	100.460	197.256	289.104	373.021	446.706	508.139
10	.468	197.209	288.913	372.554	445.797	506.597
20	.476	197.160	288.722	372.084	444.881	505.043
30	.484	197.111	288.528	371.610	443.957	503.479
40	.493	197.062	288.333	371.133	443.023	501.905
50	.501	197.012	288.137	370.652	442.091	500.320
20	100.510	196.963	287.939	370.167	441.147	498.724

TABLE VI.—MID-ORDINATES TO LONG CHORDS.

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
0° 10'	.036	.145	.327	.582	.909	1.309
20	.073	.291	.654	1.164	1.818	2.618
30	.109	.436	.982	1.745	2.727	3.926
40	.145	.582	1.309	2.327	3.686	5.235
50	.182	.727	1.636	2.909	4.545	6.544
1 10	.218	.873	1.963	3.490	5.453	7.852
20	.255	1.018	2.291	4.072	6.362	9.160
30	.291	1.164	2.618	4.654	7.270	10.468
40	.327	1.309	2.945	5.235	8.179	11.775
50	.364	1.454	3.272	5.816	9.087	13.082
2 10	.400	1.600	3.599	6.398	9.994	14.389
20	.436	1.745	3.926	6.979	10.902	15.694
30	.473	1.891	4.253	7.560	11.809	17.000
40	.509	2.036	4.580	8.141	12.716	18.304
50	.545	2.181	4.907	8.722	13.623	19.608
3 10	.582	2.327	5.234	9.303	14.529	20.912
20	.618	2.472	5.561	9.883	15.435	22.214
30	.654	2.618	5.888	10.464	16.341	23.516
40	.691	2.763	6.215	11.044	17.246	24.817
50	.727	2.908	6.542	11.624	18.151	26.117
4 10	.763	3.054	6.868	12.204	19.055	27.416
20	.800	3.199	7.195	12.784	19.959	28.714
30	.836	3.345	7.522	13.363	20.863	30.012
40	.872	3.490	7.848	13.943	21.766	31.308
50	.909	3.635	8.175	14.522	22.668	32.603
5 10	.945	3.781	8.501	15.101	23.570	33.893
20	.982	3.926	8.828	15.680	24.471	35.189
30	1.018	4.071	9.154	16.258	25.372	36.480
40	1.054	4.217	9.480	16.837	26.272	37.770
50	1.091	4.362	9.807	17.415	27.171	39.059
6 10	1.127	4.507	10.133	17.992	28.070	40.346
20	1.164	4.653	10.459	18.570	28.968	41.631
30	1.200	4.798	10.785	19.147	29.866	42.916
40	1.237	4.943	11.111	19.724	30.762	44.198
50	1.273	5.088	11.436	20.301	31.658	45.479
7 10	1.309	5.234	11.762	20.877	32.553	46.759
20	1.346	5.379	12.088	21.453	33.448	48.037
30	1.382	5.524	12.413	22.029	34.341	49.313
40	1.418	5.669	12.739	22.604	35.234	50.587
50	1.455	5.814	13.064	23.179	36.126	51.860
8 10	1.491	5.960	13.389	23.754	37.017	53.130
20	1.528	6.105	13.715	24.328	37.907	54.399
30	1.564	6.250	14.040	24.902	38.796	55.666
40	1.600	6.395	14.365	25.476	39.684	56.931
50	1.637	6.540	14.689	26.049	40.571	58.193
9 10	1.673	6.685	15.014	26.622	41.458	59.454
20	1.710	6.831	15.339	27.195	42.343	60.712
30	1.746	6.976	15.663	27.767	43.227	61.969
40	1.782	7.121	15.988	28.338	44.110	63.223
50	1.819	7.266	16.312	28.910	44.992	64.475
10 10	1.855	7.411	16.636	29.481	45.873	65.724
20	1.892	7.556	16.960	30.051	46.753	66.972
30	1.928	7.701	17.284	30.621	47.632	68.216
40	1.965	7.846	17.608	31.190	48.510	69.459
50	2.001	7.991	17.932	31.759	49.386	70.699
11 10	2.037	8.136	18.255	32.328	50.261	71.936
20	2.074	8.281	18.578	32.896	51.135	73.171
30	2.110	8.426	18.902	33.464	52.008	74.403
40	2.147	8.571	19.225	34.031	52.880	75.632
50	2.183	8.716	19.548	34.597	53.750	76.859

TABLE VI.—MID-ORDINATES TO LONG CHORDS.

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
10°						
10'	2.219	8.860	19.870	35.164	54.619	78.083
20	2.256	9.006	20.193	35.729	55.486	79.305
30	2.293	9.150	20.516	36.294	56.353	80.523
40	2.329	9.295	20.838	36.859	57.218	81.739
50	2.365	9.440	21.160	37.423	58.081	82.951
11						
10	2.402	9.585	21.483	37.986	58.943	84.161
20	2.438	9.729	21.804	38.549	59.804	85.368
30	2.475	9.874	22.126	39.111	60.663	86.571
40	2.511	10.019	22.448	39.673	61.521	87.772
50	2.547	10.164	22.769	40.234	62.377	88.969
	2.584	10.308	23.090	40.795	63.232	90.164
12						
10	2.620	10.453	23.412	41.355	64.085	91.355
20	2.657	10.597	23.733	41.914	64.937	92.542
30	2.693	10.742	24.053	42.473	65.787	93.727
40	2.730	10.887	24.374	43.031	66.636	94.908
50	2.766	11.031	24.694	43.588	67.482	96.086
	2.803	11.176	25.014	44.145	68.328	97.260
13						
10	2.839	11.320	25.334	44.701	69.171	98.431
20	2.876	11.465	25.654	45.256	70.012	99.598
30	2.912	11.609	25.974	45.811	70.854	100.762
40	2.949	11.754	26.293	46.365	71.692	101.922
50	2.985	11.898	26.612	46.919	72.529	103.079
	3.022	12.043	26.931	47.472	73.364	104.232
14						
10	3.058	12.187	27.250	48.024	74.197	105.381
20	3.095	12.331	27.569	48.575	75.029	106.527
30	3.131	12.476	27.887	49.126	75.859	107.669
40	3.168	12.620	28.206	49.676	76.687	108.807
50	3.204	12.764	28.524	50.225	77.513	109.941
	3.241	12.908	28.841	50.773	78.337	111.071
15						
10	3.277	13.053	29.159	51.321	79.159	112.197
20	3.314	13.197	29.476	51.868	79.979	113.319
30	3.350	13.341	29.794	52.414	80.798	114.438
40	3.387	13.485	30.111	52.959	81.614	115.552
50	3.423	13.629	30.427	53.504	82.429	116.662
	3.460	13.773	30.744	54.048	83.241	117.768
16						
10	3.496	13.917	31.060	54.591	84.053	118.870
20	3.533	14.061	31.376	55.133	84.861	119.967
30	3.569	14.205	31.692	55.675	85.667	121.061
40	3.606	14.349	32.008	56.215	86.471	122.150
50	3.643	14.493	32.323	56.755	87.274	123.225
	3.679	14.637	32.638	57.294	88.074	124.315
17						
10	3.716	14.781	32.953	57.832	88.872	125.391
20	3.752	14.925	33.267	58.369	89.668	126.463
30	3.789	15.069	33.582	58.906	90.462	127.530
40	3.825	15.212	33.896	59.441	91.254	128.593
50	3.862	15.356	34.210	59.976	92.043	129.651
	3.899	15.500	34.523	60.510	92.830	130.704
18						
10	3.935	15.643	34.837	61.043	93.616	131.753
20	3.972	15.787	35.150	61.574	94.398	132.797
30	4.008	15.931	35.463	62.106	95.179	133.837
40	4.045	16.074	35.775	62.636	95.957	134.872
50	4.081	16.218	36.088	63.165	96.733	135.902
	4.118	16.361	36.400	63.693	97.506	136.928
19						
10	4.155	16.505	36.712	64.221	98.278	137.948
20	4.191	16.648	37.023	64.747	99.047	138.964
30	4.228	16.792	37.334	65.273	99.813	139.975
40	4.265	16.935	37.645	65.797	100.577	140.981
50	4.301	17.078	37.956	66.321	101.339	141.982
	4.338	17.222	38.266	66.843	102.098	142.978
20						
	4.374	17.365	38.576	67.365	102.855	143.969

TABLE VII.—MINUTES IN DECIMALS OF A DEGREE.

'	0°	10°	15°	20°	30°	40°	45°	50°	'
0	.00000	.00278	.00417	.00556	.00883	.01111	.01250	.01389	0
1	.01667	.01944	.02083	.02222	.02500	.02778	.02917	.03056	1
2	.03333	.03611	.03750	.03889	.04167	.04444	.04583	.04722	2
3	.05000	.05278	.05417	.05556	.05833	.06111	.06250	.06389	3
4	.06667	.06944	.07083	.07222	.07500	.07778	.07917	.08056	4
5	.08333	.08611	.08750	.08889	.09167	.09444	.09583	.09722	5
6	.10000	.10278	.10417	.10556	.10833	.11111	.11250	.11389	6
7	.11667	.11944	.12083	.12222	.12500	.12778	.12917	.13056	7
8	.13333	.13611	.13750	.13889	.14167	.14444	.14583	.14722	8
9	.15000	.15278	.15417	.15556	.15833	.16111	.16250	.16389	9
10	.16667	.16944	.17083	.17222	.17500	.17778	.17917	.18056	10
11	.18333	.18611	.18750	.18889	.19167	.19444	.19583	.19722	11
12	.20000	.20278	.20417	.20556	.20833	.21111	.21250	.21389	12
13	.21667	.21944	.22083	.22222	.22500	.22778	.22917	.23056	13
14	.23333	.23611	.23750	.23889	.24167	.24444	.24583	.24722	14
15	.25000	.25278	.25417	.25556	.25833	.26111	.26250	.26389	15
16	.26667	.26944	.27083	.27222	.27500	.27778	.27917	.28056	16
17	.28333	.28611	.28750	.28889	.29167	.29444	.29583	.29722	17
18	.30000	.30278	.30417	.30556	.30833	.31111	.31250	.31389	18
19	.31667	.31944	.32083	.32222	.32500	.32778	.32917	.33056	19
20	.33333	.33611	.33750	.33889	.34167	.34444	.34583	.34722	20
21	.35000	.35278	.35417	.35556	.35833	.36111	.36250	.36389	21
22	.36667	.36944	.37083	.37222	.37500	.37778	.37917	.38056	22
23	.38333	.38611	.38750	.38889	.39167	.39444	.39583	.39722	23
24	.40000	.40278	.40417	.40556	.40833	.41111	.41250	.41389	24
25	.41667	.41944	.42083	.42222	.42500	.42778	.42917	.43056	25
26	.43333	.43611	.43750	.43889	.44167	.44444	.44583	.44722	26
27	.45000	.45278	.45417	.45556	.45833	.46111	.46250	.46389	27
28	.46667	.46944	.47083	.47222	.47500	.47778	.47917	.48056	28
29	.48333	.48611	.48750	.48889	.49167	.49444	.49583	.49722	29
30	.50000	.50278	.50417	.50556	.50833	.51111	.51250	.51389	30
31	.51667	.51944	.52083	.52222	.52500	.52778	.52917	.53056	31
32	.53333	.53611	.53750	.53889	.54167	.54444	.54583	.54722	32
33	.55000	.55278	.55417	.55556	.55833	.56111	.56250	.56389	33
34	.56667	.56944	.57083	.57222	.57500	.57778	.57917	.58056	34
35	.58333	.58611	.58750	.58889	.59167	.59444	.59583	.59722	35
36	.60000	.60278	.60417	.60556	.60833	.61111	.61250	.61389	36
37	.61667	.61944	.62083	.62222	.62500	.62778	.62917	.63056	37
38	.63333	.63611	.63750	.63889	.64167	.64444	.64583	.64722	38
39	.65000	.65278	.65417	.65556	.65833	.66111	.66250	.66389	39
40	.66667	.66944	.67083	.67222	.67500	.67778	.67917	.68056	40
41	.68333	.68611	.68750	.68889	.69167	.69444	.69583	.69722	41
42	.70000	.70278	.70417	.70556	.70833	.71111	.71250	.71389	42
43	.71667	.71944	.72083	.72222	.72500	.72778	.72917	.73056	43
44	.73333	.73611	.73750	.73889	.74167	.74444	.74583	.74722	44
45	.75000	.75278	.75417	.75556	.75833	.76111	.76250	.76389	45
46	.76667	.76944	.77083	.77222	.77500	.77778	.77917	.78056	46
47	.78333	.78611	.78750	.78889	.79167	.79444	.79583	.79722	47
48	.80000	.80278	.80417	.80556	.80833	.81111	.81250	.81389	48
49	.81667	.81944	.82083	.82222	.82500	.82778	.82917	.83056	49
50	.83333	.83611	.83750	.83889	.84167	.84444	.84583	.84722	50
51	.85000	.85278	.85417	.85556	.85833	.86111	.86250	.86389	51
52	.86667	.86944	.87083	.87222	.87500	.87778	.87917	.88056	52
53	.88333	.88611	.88750	.88889	.89167	.89444	.89583	.89722	53
54	.90000	.90278	.90417	.90556	.90833	.91111	.91250	.91389	54
55	.91667	.91944	.92083	.92222	.92500	.92778	.92917	.93056	55
56	.93333	.93611	.93750	.93889	.94167	.94444	.94583	.94722	56
57	.95000	.95278	.95417	.95556	.95833	.96111	.96250	.96389	57
58	.96667	.96944	.97083	.97222	.97500	.97778	.97917	.98056	58
59	.98333	.98611	.98750	.98889	.99167	.99444	.99583	.99722	59
'	0°	10°	15°	20°	30°	40°	45°	50°	'

TABLE VIII.—SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
1	1	1	1.0000000	1.0000000	1.000000000
2	4	8	1.4142136	1.2599210	.500000000
3	9	27	1.7320508	1.4422496	.333333333
4	16	64	2.0000000	1.5874011	.250000000
5	25	125	2.2360680	1.7099759	.200000000
6	36	216	2.4494897	1.8171206	.166666667
7	49	343	2.6457513	1.9129812	.142857143
8	64	512	2.8284271	2.0000000	.125000000
9	81	729	3.0000000	2.0800687	.111111111
10	100	1000	3.1622777	2.1544347	.100000000
11	121	1331	3.3166248	2.2239801	.090909091
12	144	1728	3.4641016	2.2894286	.083333333
13	169	2197	3.6055513	2.3513847	.076923077
14	196	2744	3.7416574	2.4101422	.071428571
15	225	3375	3.8729838	2.4662121	.066666667
16	256	4096	4.0000000	2.5198421	.062500000
17	289	4913	4.1231056	2.5712616	.058823529
18	324	5832	4.2426407	2.6207414	.055555556
19	361	6859	4.3588989	2.6684016	.052631579
20	400	8000	4.4721360	2.7144177	.050000000
21	441	9261	4.5825757	2.7589248	.047619048
22	484	10648	4.6904158	2.8020393	.045454545
23	529	12167	4.7958315	2.8438670	.043478261
24	576	13824	4.8989795	2.8844991	.041666667
25	625	15625	5.0000000	2.9240177	.040000000
26	676	17576	5.0990195	2.9624960	.038461538
27	729	19683	5.1961524	3.0000000	.037037037
28	784	21952	5.2915026	3.0865889	.035714286
29	841	24389	5.3851648	3.0723168	.034482759
30	900	27000	5.4772256	3.1072325	.033333333
31	961	29791	5.5677644	3.1413806	.032258065
32	1024	32768	5.6568542	3.1748021	.031250000
33	1089	35937	5.7445626	3.2075843	.030303030
34	1156	39304	5.8309519	3.2396118	.029411765
35	1225	42875	5.9160798	3.2710663	.028571429
36	1296	46656	6.0000000	3.3019272	.027777778
37	1369	50653	6.0827625	3.3322218	.027027027
38	1444	54872	6.1644140	3.3619754	.026315789
39	1521	59319	6.2449980	3.3912114	.025641026
40	1600	64000	6.3245553	3.4199519	.025000000
41	1681	68921	6.4081242	3.4482172	.024390244
42	1764	74088	6.4807407	3.4760266	.023809524
43	1849	79507	6.5574385	3.5033981	.023225681
44	1936	85184	6.6332496	3.5303483	.022727273
45	2025	91125	6.7082039	3.5568993	.022222222
46	2116	97336	6.7823300	3.5830479	.021739130
47	2209	103823	6.8556546	3.6088261	.021276600
48	2304	110592	6.9282032	3.6342411	.020833333
49	2401	117649	7.0000000	3.6598057	.020408163
50	2500	125000	7.0710678	3.6840314	.020000000
51	2601	132651	7.1414284	3.7084298	.019607843
52	2704	140608	7.2111026	3.7325111	.019230769
53	2809	148877	7.2801099	3.7562858	.018867925
54	2916	157464	7.3484692	3.7797631	.018518519
55	3025	166375	7.4161985	3.8029525	.018181818
56	3136	175616	7.4833148	3.8258624	.017857143
57	3249	185193	7.5498344	3.8485011	.017543860
58	3364	195112	7.6157731	3.8708766	.017241379
59	3481	205379	7.6811457	3.8929965	.016949153
60	3600	216000	7.7459667	3.9148676	.016666667
61	3721	226981	7.8102497	3.9364972	.016398443
62	3844	238328	7.8740079	3.9578915	.016129039

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
63	3969	250047	7.9372539	3.9790571	.015873016
64	4096	262144	8.0000000	4.0000000	.015625000
65	4225	274625	8.0622577	4.0207256	.015384615
66	4356	287496	8.1240384	4.0412401	.015151515
67	4489	300763	8.1853528	4.0615480	.014925373
68	4624	314432	8.2462113	4.0816551	.014705882
69	4761	328509	8.3066239	4.1015661	.014492754
70	4900	343000	8.3666003	4.1212853	.014285714
71	5041	357911	8.4261498	4.1408178	.014084507
72	5184	373248	8.4852814	4.1601676	.013888889
73	5329	389017	8.5440037	4.1798390	.013698630
74	5476	405224	8.6023253	4.1988364	.013513514
75	5625	421875	8.6602540	4.2171633	.013333333
76	5776	438976	8.7177979	4.2358296	.013157895
77	5929	456533	8.7749644	4.2548210	.012987013
78	6084	474552	8.8317609	4.2736536	.012820513
79	6241	493039	8.8881944	4.2926404	.012658228
80	6400	512000	8.9442719	4.3086695	.012500000
81	6561	531441	9.0000000	4.3267487	.012345679
82	6724	551368	9.0553851	4.3444815	.012195122
83	6889	571787	9.1104336	4.3620707	.012048193
84	7056	592704	9.1651514	4.3795191	.011904762
85	7225	614125	9.2195445	4.3968296	.011764706
86	7396	636056	9.2736185	4.4140049	.011627907
87	7569	658503	9.3273791	4.4310476	.011494253
88	7744	681472	9.3808315	4.4479602	.011363636
89	7921	704969	9.4339811	4.4647451	.011235955
90	8100	729000	9.4868330	4.4814047	.011111111
91	8281	753571	9.5393920	4.4979414	.010989011
92	8464	778688	9.5916630	4.5143574	.010869565
93	8649	804357	9.6436508	4.5306549	.010752668
94	8836	830584	9.6953597	4.5468359	.010638298
95	9025	857375	9.7467943	4.5629026	.010526316
96	9216	884736	9.7979590	4.5788570	.010416667
97	9409	912673	9.8488578	4.5947009	.010309278
98	9604	941192	9.8994949	4.6104363	.010204062
99	9801	970299	9.9498744	4.6260050	.010101010
100	10000	1000000	10.0000000	4.6415888	.010000000
101	10201	1030301	10.0498756	4.6570095	.009900990
102	10404	1061208	10.0995049	4.6723287	.009808922
103	10609	1092727	10.1488916	4.6875482	.009706738
104	10816	1124864	10.1980390	4.7026694	.009615385
105	11025	1157625	10.2469508	4.7176940	.009523810
106	11236	1191016	10.2956301	4.7326235	.009433962
107	11449	1225043	10.3440804	4.7474594	.009345794
108	11664	1259712	10.3923048	4.7622032	.009259259
109	11881	1295029	10.4403065	4.7768562	.009174312
110	12100	1331000	10.4880885	4.7914199	.009090909
111	12321	1367631	10.5356538	4.8058953	.009009009
112	12544	1404928	10.5830052	4.8202845	.008928571
113	12769	1442897	10.6301458	4.8345881	.008849558
114	12996	1481544	10.6770783	4.8488076	.008771930
115	13225	1520875	10.7238053	4.8629442	.008695652
116	13456	1560896	10.7703296	4.8769990	.008620690
117	13689	1601613	10.8166538	4.8909732	.008547009
118	13924	1643032	10.8627805	4.9048681	.008474576
119	14161	1685159	10.9087121	4.9186847	.008403361
120	14400	1728000	10.9544512	4.9324242	.008333333
121	14641	1771561	11.00.0000	4.9460874	.008264463
122	14884	1815848	11.0453610	4.9596757	.008196721
123	15129	1860867	11.0905865	4.9731898	.008130081
124	15376	1906624	11.1355287	4.9866310	.008064516

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
125	15625	1953125	11.1803399	5.0000000	.008000000
126	15876	2000376	11.2349723	5.0132979	.007936508
127	16129	2048383	11.2694277	5.0265257	.007874016
128	16384	2097152	11.3137085	5.0396842	.007812500
129	16641	2146689	11.3578167	5.0527743	.007751988
130	16900	2197000	11.4017543	5.0657970	.007692308
131	17161	2248091	11.4455231	5.0787531	.007633588
132	17424	2299968	11.4891253	5.0916434	.007575758
133	17689	2352637	11.5325628	5.1044687	.007518797
134	17956	2406104	11.5758369	5.1172299	.007462687
135	18225	2460375	11.6189500	5.1299278	.007407407
136	18496	2515456	11.6619038	5.1425632	.007352941
137	18769	2571353	11.7046999	5.1551867	.007299270
138	19044	2628072	11.7473401	5.1676493	.007246377
139	19321	2685619	11.7898261	5.1801015	.007194245
140	19600	2744000	11.8321596	5.1924941	.007142857
141	19881	2803221	11.8743421	5.2048279	.007092199
142	20164	2863288	11.9163753	5.2171034	.007042254
143	20449	2924207	11.9582607	5.2293215	.006993007
144	20736	2985984	12.0000000	5.2414828	.006944444
145	21025	3048625	12.0415946	5.2535879	.006896552
146	21316	3112136	12.0830460	5.2656374	.006849315
147	21609	3176523	12.1243557	5.2776321	.006802721
148	21904	3241792	12.1655251	5.2895735	.006756757
149	22201	3307949	12.2065556	5.3014592	.006711409
150	22500	3375000	12.2474487	5.3132928	.006666667
151	22801	3442951	12.2882057	5.3250740	.006622517
152	23104	3511808	12.3288280	5.3368083	.006578947
153	23409	3581577	12.3693169	5.3484812	.006535948
154	23716	3652264	12.4096736	5.3601084	.006493508
155	24025	3723875	12.4498996	5.3716854	.006451613
156	24336	3796416	12.4899960	5.3832126	.006410256
157	24649	3869893	12.5299641	5.3946907	.006369427
158	24964	3944312	12.5698051	5.4061208	.006329114
159	25281	4019679	12.6095202	5.4175015	.006289308
160	25600	4096000	12.6491106	5.4288352	.006250000
161	25921	4173281	12.6885775	5.4401218	.006211180
162	26244	4251528	12.7279221	5.4513618	.006172840
163	26569	4330747	12.7671453	5.4625556	.006134969
164	26896	4410944	12.8062485	5.4737087	.006097561
165	27225	4492125	12.8452326	5.4848066	.006060606
166	27556	4574296	12.8840987	5.4958647	.006024096
167	27889	4657463	12.9228480	5.5068784	.005989024
168	28224	4741632	12.9614814	5.5178484	.005954231
169	28561	4826809	13.0000000	5.5287748	.005917160
170	28900	4913000	13.0384048	5.5396588	.005882353
171	29241	5000211	13.0766968	5.5504991	.005847953
172	29584	5088448	13.1148770	5.5612978	.005813863
173	29929	5177717	13.1529464	5.5720546	.005780047
174	30276	5268024	13.1909060	5.5827702	.005747126
175	30625	5359375	13.2287566	5.5934447	.005714286
176	30976	5451776	13.2664992	5.6040787	.005681818
177	31329	5545233	13.3041847	5.6146724	.005649718
178	31684	5639752	13.3416641	5.6252263	.005617978
179	32041	5735339	13.3790882	5.6357408	.005586592
180	32400	5832000	13.4164079	5.6462162	.005555556
181	32761	5929741	13.4536240	5.6566528	.005524862
182	33124	6028568	13.4907376	5.6670511	.005494505
183	33489	6128487	13.5277493	5.6774114	.005464481
184	33856	6229504	13.5646600	5.6877340	.005434733
185	34225	6331625	13.6014705	5.6980192	.005405405
186	34596	6434856	13.6381817	5.7082675	.005376344

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
187	34969	6589208	13.6747943	5.7184791	.005347594
188	35344	6644672	13.7113092	5.7286543	.005319149
189	35721	6751269	13.7477271	5.7387936	.005291005
190	36100	6859000	13.7840483	5.7488971	.005263158
191	36481	6967871	13.8202750	5.7589652	.005235602
192	36864	7077888	13.8564065	5.7689962	.005208333
193	37249	7189057	13.8924440	5.7789966	.005181347
194	37636	7301384	13.9283883	5.7889604	.005154639
195	38025	7414875	13.9642400	5.7988900	.005128205
196	38416	7529536	14.0000000	5.8087857	.005102041
197	38809	7645373	14.0356688	5.8186479	.005076142
198	39204	7762392	14.0712473	5.8284767	.005050505
199	39601	7880599	14.1067360	5.8382725	.005025126
200	40000	8000000	14.1421356	5.8480355	.005000000
201	40401	8120601	14.1774469	5.8577660	.004975124
202	40804	8242408	14.2126704	5.8674643	.004950495
203	41209	8365427	14.2478068	5.8771307	.004926108
204	41616	8489664	14.2828569	5.8867653	.004901961
205	42025	8615125	14.3178211	5.8963685	.004878049
206	42436	8741816	14.3527001	5.9059406	.004854369
207	42849	8869743	14.3874946	5.9154817	.004830918
208	43264	8998912	14.4222051	5.9249921	.004807692
209	43681	9129329	14.4568323	5.9344721	.004784689
210	44100	9261000	14.4913767	5.9439220	.004761905
211	44521	9393931	14.5258390	5.9533418	.004739336
212	44944	9528128	14.5602198	5.9627320	.004716981
213	45369	9663597	14.5945195	5.9720926	.004694836
214	45796	9800344	14.6287388	5.9814240	.004672897
215	46225	9938375	14.6628783	5.9907264	.004651163
216	46656	10077696	14.6969385	6.0000000	.004629630
217	47089	10218313	14.7309199	6.0092450	.004608295
218	47524	10360232	14.7648231	6.0184617	.004587156
219	47961	10503459	14.7986486	6.0276502	.004566210
220	48400	10648000	14.8323970	6.0368107	.004545455
221	48841	10793861	14.8660687	6.0459435	.004524887
222	49284	10941048	14.8996644	6.0550489	.004504505
223	49729	11089567	14.9331845	6.0641270	.004484305
224	50176	11239424	14.9666295	6.0731779	.004464286
225	50625	11390625	15.0000000	6.0822020	.004444444
226	51076	11543176	15.0332964	6.0911994	.004424779
227	51529	11697083	15.0665192	6.1001702	.004405286
228	51984	11852352	15.0996689	6.1091147	.004385965
229	52441	12009989	15.1327460	6.1180332	.004366812
230	52900	12169000	15.1657509	6.1269257	.004347826
231	53361	12329391	15.1986842	6.1357924	.004329004
232	53824	12487168	15.2315462	6.1446387	.004310345
233	54289	12643337	15.2643375	6.1534495	.004291845
234	54756	12801204	15.2970585	6.1622401	.004273504
235	55225	12977875	15.3297097	6.1710058	.004255319
236	55696	13144256	15.3622915	6.1797466	.004237288
237	56169	13312053	15.3948043	6.1884628	.004219409
238	56644	13481272	15.4272486	6.1971544	.004201681
239	57121	13651919	15.4596248	6.2058218	.004184100
240	57600	13824000	15.4919334	6.2144650	.004166667
241	58081	13997521	15.5241747	6.2230843	.004149378
242	58564	14172488	15.5563492	6.2316797	.004132231
243	59049	14348907	15.5884573	6.2402515	.004115226
244	59536	14526784	15.6204994	6.2487998	.004098361
245	60025	14706125	15.6524758	6.2573248	.004081633
246	60516	14886936	15.6843371	6.2658266	.004065041
247	61009	15069223	15.7162336	6.2743054	.004048563
248	61504	15252992	15.7480157	6.2827618	.004032258

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
249	62001	15488249	15.7797338	6.2911946	.004016064
250	62500	15625000	15.8118883	6.2996053	.004000000
251	63001	15813251	15.8429795	6.3079935	.003984064
252	63504	16003008	15.8745079	6.3163596	.003968254
253	64009	16194277	15.9059737	6.3247035	.003952569
254	64516	16387064	15.9373773	6.3330256	.003937008
255	65025	16581375	15.9687194	6.3413257	.003921569
256	65536	16777216	16.0000000	6.3496042	.003906250
257	66049	16974593	16.0312195	6.3578611	.003891051
258	66564	17173512	16.0623784	6.3660968	.003875969
259	67081	17373979	16.0934769	6.3743111	.003861004
260	67600	17576000	16.1245155	6.3825043	.003846154
261	68121	17779581	16.1554944	6.3906765	.003831418
262	68644	17984728	16.1864141	6.3988279	.003816794
263	69169	18191447	16.2172747	6.4069585	.003802281
264	69696	18399744	16.2480768	6.4150687	.003787879
265	70225	18609625	16.2788206	6.4231583	.003773585
266	70756	18821096	16.3095064	6.4312276	.003759398
267	71289	19034163	16.3401946	6.4392767	.003745318
268	71824	19248832	16.3707055	6.4473057	.003731343
269	72361	19465109	16.4012195	6.4553148	.003717472
270	72900	19683000	16.4316767	6.4633041	.003703704
271	73441	19902511	16.4620776	6.4712736	.003690037
272	73984	20123648	16.4924225	6.4792236	.003676471
273	74529	20346417	16.5227116	6.4871541	.003663004
274	75076	20570824	16.5529454	6.4950653	.003649635
275	75625	20796875	16.5831240	6.5029572	.003636364
276	76176	21024576	16.6132477	6.5108300	.003623188
277	76729	21253933	16.6433170	6.5186839	.003610108
278	77284	21484952	16.6733320	6.5265189	.003597123
279	77841	21717639	16.7032981	6.5343351	.003584229
280	78400	21952000	16.7332005	6.5421326	.003571429
281	78961	22188041	16.7630546	6.5499116	.003558719
282	79524	22425768	16.7928556	6.5576722	.003546099
283	80089	22665187	16.8226038	6.5654144	.003533569
284	80656	22906304	16.8522995	6.5731385	.003521127
285	81225	23149125	16.8819430	6.5808443	.003508772
286	81796	23393656	16.9115345	6.5885323	.003496503
287	82369	23639903	16.9410743	6.5962023	.003484321
288	82944	23887872	16.9705627	6.6038545	.003472222
289	83521	24137569	17.0000000	6.6114890	.003460208
290	84100	24388900	17.0293864	6.6191060	.003448276
291	84681	24642171	17.0587221	6.6267054	.003436426
292	85264	24897088	17.0880075	6.6342874	.003424658
293	85849	25153757	17.1172428	6.6418522	.003412969
294	86436	25412184	17.1464262	6.6493998	.003401361
295	87025	25672375	17.1755640	6.6569302	.003389831
296	87616	25934336	17.2046505	6.6644437	.003378378
297	88209	26198073	17.2336879	6.6719403	.003366703
298	88804	26463592	17.2626765	6.6794200	.003355705
299	89401	26730899	17.2916165	6.6868831	.003344432
300	90000	27000000	17.3205081	6.6943225	.003333333
301	90601	27270901	17.3493510	6.7017593	.003322259
302	91204	27543608	17.3781472	6.7091729	.003311258
303	91809	27818127	17.4068952	6.7165700	.003300308
304	92416	28094464	17.4355958	6.7239508	.003289474
305	93025	28372625	17.4642492	6.7313155	.003278659
306	93636	28652616	17.4928557	6.7386641	.003267974
307	94249	28934443	17.5214155	6.7459967	.003257329
308	94864	29218112	17.5499288	6.7533134	.003246753
309	95481	29503629	17.5783958	6.7606143	.003236246
310	96100	29791000	17.6068169	6.7678995	.003225806

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
811	96721	80060231	17.6851921	6.7751690	.003215434
812	97344	80371828	17.6635217	6.7824229	.003205128
813	97969	80684297	17.6918060	6.7896613	.003194858
814	98596	80999144	17.7200451	6.7968844	.003184713
815	99225	81255875	17.7482393	6.8040921	.003174603
816	99856	81554496	17.7763888	6.8112847	.003164557
817	100489	81855013	17.8044938	6.8184620	.003154574
818	101124	82157432	17.8325545	6.8256242	.003144654
819	101761	82461759	17.8605711	6.8327714	.003134796
820	102400	82768000	17.8885438	6.8399037	.003125000
821	103041	83076161	17.9164729	6.8470213	.003115265
822	103684	83386248	17.9443584	6.8541240	.003105590
823	104329	83698267	17.9722008	6.8612120	.003095975
824	104976	84012224	18.0000000	6.8682855	.003086420
825	105625	84328125	18.0277564	6.8753443	.003076923
826	106276	84645976	18.0554701	6.8823888	.003067485
827	106929	84965783	18.0831413	6.8894188	.003058104
828	107584	85287552	18.1107703	6.8964345	.003048780
829	108241	85611289	18.1383571	6.9034359	.003039514
830	108900	85937000	18.1659021	6.9104232	.003030303
831	109561	86264691	18.1934054	6.9173964	.003021148
832	110224	86594368	18.2208672	6.9243556	.003012048
833	110889	86926037	18.2482876	6.9313008	.003003003
834	111556	87259704	18.2756669	6.9382321	.002994012
835	112225	87595375	18.3030052	6.9451496	.002985075
836	112896	87933056	18.3303028	6.9520533	.002976190
837	113569	88272753	18.3575598	6.9589434	.002967359
838	114244	88614472	18.3847763	6.9658198	.002958580
839	114921	88958219	18.4119526	6.9726826	.002949853
840	115600	89304000	18.4390889	6.9795321	.002941176
841	116281	89651821	18.4661853	6.9863681	.002932551
842	116964	90001688	18.4932420	6.9931906	.002923977
843	117649	90353607	18.5202592	7.0000000	.002915452
844	118336	90707584	18.5472370	7.0067962	.002906977
845	119025	91063625	18.5741756	7.0135791	.002898551
846	119716	91421736	18.6010752	7.0203490	.002890173
847	120409	91781923	18.6279360	7.0271068	.002881844
848	121104	92144192	18.6547581	7.0338497	.002873563
849	121801	92508549	18.6815417	7.0405806	.002865330
850	122500	92875000	18.7082869	7.0472987	.002857143
851	123201	93243551	18.7349940	7.0540041	.002849003
852	123904	93614208	18.7616630	7.0606987	.002840909
853	124609	93986977	18.7882942	7.0673767	.002832861
854	125316	94361864	18.8148877	7.0740440	.002824859
855	126025	94738875	18.8414437	7.0806988	.002816901
856	126736	95118016	18.8679623	7.0873411	.002808989
857	127449	95499293	18.8944436	7.0939709	.002801120
858	128164	95882712	18.9208879	7.1005885	.002793296
859	128881	96268279	18.9472953	7.1071937	.002785515
860	129600	96656000	18.9736660	7.1137866	.002777778
861	130321	97045881	19.0000000	7.1203674	.002770063
862	131044	97437928	19.0262976	7.1269360	.002762431
863	131769	97832147	19.0525589	7.1334925	.002754821
864	132496	98228544	19.0787840	7.1400370	.002747253
865	133225	98627125	19.1049732	7.1465695	.002739726
866	133956	99027896	19.1311265	7.1530901	.002732240
867	134689	99430863	19.1572441	7.1595968	.002724796
868	135424	99836032	19.1833261	7.1660957	.002717391
869	136161	100243409	19.2093727	7.1725809	.002710027
870	136900	100653000	19.2353841	7.1790544	.002702703
871	137641	101064811	19.2613603	7.1855162	.002695418
872	138384	101478848	19.2873015	7.1919668	.002688172

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
873	139129	51895117	19.8132079	7.1984050	.002680965
874	139876	52313624	19.8390796	7.2048322	.002673797
875	140625	52734375	19.8649167	7.2112479	.002666667
876	141376	53157376	19.8907194	7.2176522	.002659574
877	142129	53582633	19.4164878	7.2240450	.002652520
878	142884	54010152	19.4422221	7.2304268	.002645503
879	143641	54439989	19.4679223	7.2367972	.002638522
880	144400	54872000	19.4935887	7.2431565	.002631579
881	145161	55306341	19.5192213	7.2495045	.002624672
882	145924	55742968	19.5448203	7.2558415	.002617801
883	146689	56181887	19.5703853	7.2621675	.002610966
884	147456	56623104	19.5959179	7.2684824	.002604167
885	148225	57066625	19.6214169	7.2747864	.002597403
886	148996	57512456	19.6468827	7.2810794	.002590674
887	149769	57960603	19.6723156	7.2873617	.002583979
888	150544	58411072	19.6977156	7.2936330	.002577320
889	151321	58863869	19.7230629	7.2998936	.002570694
890	152100	59319000	19.7484177	7.3061436	.002564103
891	152881	59776471	19.7737199	7.3123828	.002557545
892	153664	60236288	19.7989699	7.3186114	.002551020
893	154449	60698457	19.8242276	7.3248295	.002544529
894	155236	61162984	19.8494332	7.3310369	.002538071
895	156025	61629875	19.8746069	7.3372239	.002531646
896	156816	62099136	19.8997487	7.3434205	.002525253
897	157609	62570773	19.9248588	7.3495966	.002518892
898	158404	63044792	19.9499373	7.3557624	.002512563
899	159201	63521199	19.9749844	7.3619178	.002506266
900	160000	64000000	20.0000000	7.3680630	.002500000
901	160801	64481201	20.0249844	7.3741979	.002493766
902	161604	64964808	20.0499377	7.3803227	.002487562
903	162409	65450827	20.0748599	7.3864373	.002481390
904	163216	65939264	20.0997512	7.3925418	.002475248
905	164025	66430125	20.1246118	7.3986363	.002469136
906	164836	66923416	20.1494417	7.4047206	.002463054
907	165649	67419143	20.1742410	7.4107950	.002457002
908	166464	67917312	20.1990099	7.4168595	.002450980
909	167281	68417929	20.2237484	7.4229142	.002444988
910	168100	68921000	20.2484567	7.4289589	.002439024
911	168921	69426531	20.2731349	7.4349938	.002433090
912	169744	69934528	20.2977781	7.4410189	.002427184
913	170569	70444997	20.3224014	7.4470342	.002421308
914	171396	70957944	20.3469899	7.4530399	.002415459
915	172225	71473375	20.3715488	7.4590359	.002409639
916	173056	71991296	20.3960781	7.4650223	.002403846
917	173889	72511713	20.4205779	7.4709991	.002398082
918	174724	73034632	20.4450483	7.4769664	.002392344
919	175561	73560059	20.4694895	7.4829242	.002386635
920	176400	74088000	20.4939015	7.4888724	.002380952
921	177241	74618461	20.5182845	7.4948113	.002375297
922	178084	75151448	20.5426386	7.5007406	.002369668
923	178929	75686967	20.5669638	7.5066607	.002364066
924	179776	76225024	20.5912603	7.5125715	.002358491
925	180625	76765625	20.6155281	7.5184730	.002352941
926	181476	77308776	20.6397674	7.5243652	.002347418
927	182329	77854483	20.6639783	7.5302482	.002341920
928	183184	78402752	20.6881609	7.5361221	.002336449
929	184041	78953589	20.7123152	7.5419867	.002331002
930	184900	79507000	20.7364414	7.5478423	.002325581
931	185761	80062991	20.7605395	7.5536888	.002320186
932	186624	80621568	20.7846097	7.5595263	.002314815
933	187489	81182737	20.8086520	7.5653548	.002309469
934	188356	81746504	20.8326667	7.5711743	.002304147

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
435	189225	82312875	20.8566536	7.5769849	.002298851
436	190096	82881856	20.8906130	7.5827865	.002293578
437	190969	83453453	20.9045450	7.5885793	.002288390
438	191844	84028773	20.9284495	7.5943633	.002283105
439	192721	84604519	20.9523268	7.6001385	.002277904
440	193600	85184000	20.9761770	7.6059049	.002272727
441	194481	85766121	21.0000000	7.6116626	.002267574
442	195304	86350688	21.0237960	7.6174116	.002262443
443	196249	86938907	21.0475652	7.6231519	.002257396
444	197136	87528384	21.0718075	7.6288837	.002252352
445	198025	881212125	21.09550231	7.6346067	.002247191
446	198916	88716536	21.1187121	7.6403213	.002242152
447	199809	89314623	21.1423745	7.6460272	.002237186
448	200704	89915302	21.1660105	7.6517247	.002232143
449	201601	90518849	21.1896201	7.6574133	.002227171
450	202500	91125000	21.2132084	7.6630943	.002222222
451	203401	91733551	21.2367606	7.6687665	.002217295
452	204304	92345408	21.2602916	7.6744393	.002212389
453	205209	92959677	21.2837967	7.6800857	.002207506
454	206116	93576654	21.3072758	7.6857328	.002202643
455	207025	94196375	21.3307290	7.6913717	.002197802
456	207936	94818816	21.3541565	7.6970023	.002192982
457	208849	95443993	21.3775583	7.7026246	.002188184
458	209764	96071912	21.4009846	7.7082388	.002183406
459	210681	96702579	21.4242853	7.7138448	.002178649
460	211600	97336000	21.4476106	7.7194426	.002173918
461	212521	97972181	21.4709106	7.7250325	.002169197
462	213444	98611128	21.4941853	7.7306141	.002164502
463	214369	99252847	21.5174348	7.7361877	.002159827
464	215296	99897344	21.5406592	7.7417532	.002155172
465	216225	100544625	21.5638587	7.7473109	.002150538
466	217156	101194606	21.5870831	7.7528606	.002145923
467	218089	101847503	21.6101828	7.7584023	.002141328
468	219024	102503232	21.6333077	7.7639361	.002136752
469	219961	103161709	21.6564078	7.7694620	.002132196
470	220900	103823000	21.6794884	7.7749801	.002127660
471	221841	104487111	21.7025344	7.7804904	.002123142
472	222784	105154048	21.7255610	7.7859928	.002118644
473	223729	105823817	21.7485632	7.7914875	.002114165
474	224676	106496424	21.7715411	7.7969745	.002109705
475	225625	107171875	21.7944947	7.8024538	.002105263
476	226576	107850176	21.8174242	7.8079254	.002100840
477	227529	108531333	21.8403297	7.8133892	.002096436
478	228484	109215352	21.8632111	7.8188456	.002092050
479	229441	109902239	21.8860686	7.8242942	.002087683
480	230400	110592000	21.9089023	7.8297353	.002083333
481	231361	111284641	21.9317122	7.8351688	.002079002
482	232324	111980168	21.9544984	7.8405949	.002074689
483	233289	112678587	21.9772610	7.8460134	.002070393
484	234256	113379904	22.0000000	7.8514244	.002066116
485	235225	114084125	22.0227155	7.8568251	.002061856
486	236196	114791256	22.0454077	7.8622242	.002057613
487	237169	115501303	22.0680765	7.8676190	.002053388
488	238144	116214272	22.0907220	7.8729944	.002049180
489	239121	116930169	22.1133444	7.8783684	.002044990
490	240100	117649000	22.1359496	7.8837352	.002040816
491	241081	118370771	22.1585198	7.8890946	.002036660
492	242064	119095488	22.1810730	7.8944463	.002032520
493	243049	119823157	22.2036033	7.8997917	.002028398
494	244036	120553784	22.2261108	7.9051294	.002024291
495	245025	121287375	22.2485955	7.9104599	.002020202
496	246016	122023936	22.2710575	7.9157832	.002016129

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
497	247009	122763473	22.2934968	7.9210994	.002012072
498	248004	123505092	22.3159136	7.9264065	.002006032
499	249001	124251499	22.33883079	7.9317104	.002000468
500	250000	125000000	22.3606798	7.9370053	.002000000
501	251001	125751501	22.3830293	7.9422981	.001996003
502	252004	126506008	22.4058565	7.9475739	.001992032
503	253009	127263527	22.4276615	7.9528477	.001988072
504	254016	128024064	22.4499443	7.9581144	.001984127
505	255025	128787625	22.4722051	7.9633743	.001980198
506	256036	129554216	22.4944438	7.9686271	.001976285
507	257049	130323843	22.5166605	7.9738731	.001972387
508	258064	131096512	22.5388553	7.9791122	.001968504
509	259081	131872229	22.5610283	7.9843444	.001964637
510	260100	132651000	22.5831796	7.9895697	.001960784
511	261121	133432831	22.6053091	7.9947883	.001956947
512	262144	134217728	22.6274170	8.0000000	.001953125
513	263169	135005697	22.6495033	8.0052049	.001949318
514	264196	135796744	22.6715681	8.0104032	.001945525
515	265225	136590875	22.6936114	8.0155946	.001941743
516	266256	137388096	22.7156334	8.0207794	.001937984
517	267289	138188413	22.7376340	8.0259574	.001934236
518	268324	138991832	22.7596134	8.0311287	.001930502
519	269361	139798350	22.7815715	8.0362935	.001926782
520	270400	140608000	22.8035085	8.0414515	.001923077
521	271441	141420761	22.8254244	8.0466030	.001919386
522	272484	142236648	22.8473193	8.0517479	.001915709
523	273529	143055667	22.8691933	8.0568862	.001912046
524	274576	143877824	22.8910463	8.0620180	.001908397
525	275625	144703125	22.9128785	8.0671432	.001904762
526	276676	145531576	22.9346899	8.0722620	.001901141
527	277729	146363183	22.9564806	8.0773743	.001897533
528	278784	147197952	22.9782506	8.0824800	.001893939
529	279841	148035889	23.0000000	8.0875794	.001890359
530	280900	148877000	23.0217289	8.0926723	.001886792
531	281961	149721201	23.0434372	8.0977589	.001883239
532	283024	150568768	23.0651252	8.1028390	.001879699
533	284089	151419437	23.0867928	8.1079128	.001876173
534	285156	152273304	23.1084400	8.1129803	.001872659
535	286225	153130375	23.1300670	8.1180414	.001869159
536	287296	153990656	23.1516738	8.1230962	.001865672
537	288369	154854153	23.1732605	8.1281447	.001862197
538	289444	155720872	23.1948270	8.1331870	.001858736
539	290521	156590619	23.2163735	8.1382230	.001855288
540	291600	157464000	23.2379001	8.1432529	.001851852
541	292681	158340421	23.2594067	8.1482765	.001848429
542	293764	159220068	23.2808935	8.1532939	.001845018
543	294849	160102907	23.3023604	8.1583051	.001841621
544	295936	1609889184	23.3238076	8.1633102	.001838235
545	297025	1618778625	23.3452351	8.1683092	.001834862
546	298116	1627711396	23.3666429	8.1733020	.001831502
547	299209	1636678223	23.3880311	8.1782888	.001828154
548	300304	164566592	23.4093998	8.1832695	.001824818
549	301401	165468419	23.4307490	8.1882441	.001821494
550	302500	166373000	23.4520788	8.1932127	.001818182
551	303601	167284151	23.4733892	8.1981752	.001814882
552	304704	168196608	23.4946902	8.2031319	.001811594
553	305809	169112377	23.5159520	8.2080825	.001808318
554	306916	170031464	23.5372046	8.2130271	.001805054
555	308025	170953875	23.5584380	8.2179657	.001801802
556	309136	171879616	23.5796522	8.2228985	.001798561
557	310249	172808693	23.6008474	8.2278254	.001795332
558	311364	173741112	23.6220236	8.2327463	.001792115

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
559	312481	174676879	23.6431808	8.2376614	.001788909
560	313600	175616000	23.6643191	8.2425706	.001785714
561	314721	176558481	23.6854386	8.2474740	.001782531
562	315844	177504328	23.7065392	8.2523715	.001779359
563	316969	178453547	23.7276210	8.2572633	.001776199
564	318096	179406144	23.7486842	8.2621492	.001773050
565	319225	180362125	23.7697296	8.2670294	.001769912
566	320356	181321496	23.7907545	8.2719039	.001766784
567	321489	182284263	23.8117618	8.2767726	.001763668
568	322624	183250432	23.8327506	8.2816355	.001760563
569	323761	184220000	23.8537209	8.2864928	.001757469
570	324900	185193000	23.8746728	8.2913444	.001754386
571	326041	186169411	23.8956063	8.2961903	.001751313
572	327184	187149248	23.9165215	8.3010304	.001748252
573	328329	188132517	23.9374184	8.3058651	.001745201
574	329476	189119224	23.9582971	8.3106941	.001742160
575	330625	190109375	23.9791578	8.3155175	.001739130
576	331776	191102976	24.0000000	8.3203353	.001736111
577	332929	192100033	24.0208243	8.3251475	.001733102
578	334084	193100552	24.0416303	8.3299542	.001730104
579	335241	194104529	24.0624188	8.3347553	.001727116
580	336400	195112000	24.0831891	8.3395509	.001724133
581	337561	196122941	24.1039416	8.3443410	.001721170
582	338724	197137368	24.1246762	8.3491256	.001718213
583	339889	198155287	24.1453929	8.3539047	.001715266
584	341056	199176704	24.1660919	8.3586784	.001712329
585	342225	200201625	24.1867732	8.3634466	.001709402
586	343396	201230056	24.2074360	8.3682095	.001706485
587	344569	202262003	24.2280820	8.3729668	.001703578
588	345744	203297472	24.2487113	8.3777188	.001700680
589	346921	204336469	24.2693222	8.3824653	.001697793
590	348100	205379000	24.2899156	8.3872065	.001694915
591	349281	206425071	24.3104916	8.3919423	.001692047
592	350464	207474688	24.3310501	8.3966729	.001689189
593	351649	208527857	24.3515913	8.4013981	.001686341
594	352836	209584584	24.3721152	8.4061180	.001683502
595	354025	210644875	24.3926218	8.4108326	.001680672
596	355216	211708736	24.4131112	8.4155419	.001677852
597	356409	212776173	24.4335834	8.4202460	.001675042
598	357604	213847192	24.4540385	8.4249448	.001672241
599	358801	214921799	24.4744765	8.4296383	.001669449
600	360000	216000000	24.4948974	8.4343267	.001666667
601	361201	217081801	24.5153013	8.4390098	.001663894
602	362404	218167208	24.5356883	8.4436877	.001661130
603	363609	219256227	24.5560583	8.4483605	.001658375
604	364816	220348864	24.5764115	8.4530281	.001655629
605	366025	221445125	24.5967478	8.4576906	.001652893
606	367236	222545016	24.6170673	8.4623479	.001650165
607	368449	223648543	24.6373700	8.4670001	.001647446
608	369664	224755712	24.6576560	8.4716471	.001644737
609	370881	225866529	24.6779254	8.4762892	.001642036
610	372100	226981000	24.6981781	8.4809261	.001639344
611	373321	228099131	24.7184142	8.4855579	.001636661
612	374544	229220928	24.7386338	8.4901848	.001633987
613	375769	230346397	24.7588368	8.4948065	.001631321
614	376996	231475544	24.7790234	8.4994233	.001628664
615	378225	232608375	24.7991935	8.5040350	.001626016
616	379456	233744896	24.8193473	8.5086417	.001623377
617	380689	234885113	24.8394847	8.5132435	.001620746
618	381924	236029063	24.8596058	8.5178403	.001618123
619	383161	237176859	24.8797106	8.5224321	.001615509
620	384400	238328000	24.8997992	8.5270189	.001612908

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
621	385641	239489061	24.9198716	8.5816009	.001610806
622	386684	240641848	24.8399278	8.5861780	.001607717
623	388129	241804867	24.9599679	8.5407501	.001605186
624	389376	242970624	24.9799920	8.5453173	.001602564
625	390625	244140625	25.0000000	8.5498797	.001600000
626	391876	245314376	25.0199920	8.5544372	.001597444
627	393129	246491883	25.0399681	8.5589899	.001594896
628	394384	247673152	25.0599282	8.5635377	.001592357
629	395641	248858189	25.0798724	8.5680807	.001589825
630	396900	250047000	25.0998008	8.5726189	.001587302
631	398161	251239591	25.1197134	8.5771523	.001584786
632	399424	252435968	25.1396102	8.5816809	.001582278
633	400689	253636137	25.1594913	8.5862047	.001579779
634	401956	254840104	25.1793566	8.5907238	.001577287
635	403225	256047875	25.1992063	8.5952380	.001574803
636	404496	257259456	25.2190404	8.5997476	.001572327
637	405769	258474853	25.2388589	8.6042525	.001569850
638	407044	259694072	25.2586619	8.6087526	.001567396
639	408321	260917119	25.2784493	8.6132480	.001564945
640	409600	262144000	25.2982218	8.6177388	.001562500
641	410881	263374721	25.3179778	8.6222248	.001560062
642	412164	264609288	25.3377189	8.6267063	.001557632
643	413449	265847707	25.3574447	8.6311830	.001555210
644	414736	267089984	25.3771551	8.6356551	.001552795
645	416025	268336125	25.3968502	8.6401226	.001550388
646	417316	269586136	25.4165301	8.6445855	.001547986
647	418609	270840023	25.4361947	8.6490437	.001545585
648	419904	272097792	25.4558441	8.6534974	.001543210
649	421201	273359449	25.4754784	8.6579465	.001540832
650	422500	274625000	25.4950976	8.6623911	.001538462
651	423801	275894451	25.5147016	8.6668310	.001536098
652	425104	277167808	25.5342907	8.6712665	.001533742
653	426409	278445077	25.5538647	8.6756974	.001531394
654	427716	279726264	25.5734237	8.6801237	.001529052
655	429025	281011375	25.5929678	8.6845456	.001526718
656	430336	282300416	25.6124969	8.6889630	.001524390
657	431649	283593393	25.6320112	8.6933759	.001522070
658	432964	284890312	25.6515107	8.6977843	.001519757
659	434281	286191179	25.6709953	8.7021882	.001517451
660	435600	287496000	25.6904652	8.7065877	.001515152
661	436921	288804781	25.7099203	8.7109827	.001512859
662	438244	290117528	25.7293607	8.7153734	.001510574
663	439569	291434247	25.7487864	8.7197596	.001508296
664	440896	292754944	25.7681975	8.7241414	.001506024
665	442225	294079625	25.7875939	8.7285187	.001503759
666	443556	295408296	25.8069758	8.7328918	.001501502
667	444889	296740963	25.8263431	8.7372604	.001499250
668	446224	298077682	25.8456960	8.7416246	.001497006
669	447561	299418309	25.8650343	8.7459846	.001494768
670	448900	300763000	25.8843582	8.7503401	.001492537
671	450241	302111711	25.9036677	8.7546913	.001490313
672	451584	303464448	25.9229628	8.7590383	.001488095
673	452929	304821217	25.9422435	8.7633809	.001485884
674	454276	306182024	25.9615100	8.7677192	.001483680
675	455625	307546875	25.9807621	8.7720532	.001481481
676	456976	308915776	26.0000000	8.7763830	.001479290
677	458329	310288733	26.0192237	8.7807084	.001477105
678	459684	311665752	26.0384331	8.7850296	.001474926
679	461041	313046839	26.0576284	8.7893466	.001472754
680	462400	314432000	26.0768096	8.7936593	.001470588
681	463761	315821241	26.0959787	8.7979679	.001468429
682	465124	317214568	26.1151297	8.8022721	.001466276

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
688	466489	318611987	26.1842687	8.8065723	.001464129
689	467856	320013504	26.1586987	8.8106881	.001461988
690	469225	321419125	26.1725047	8.8151598	.001459654
691	470596	322828856	26.1916017	8.8194474	.001457726
692	471969	324242703	26.2106848	8.8237907	.001455604
693	473344	325660673	26.2297541	8.8280099	.001453488
694	474721	327082769	26.2488095	8.8322850	.001451379
695	476100	328509000	26.2678511	8.8365559	.001449275
696	477481	329939371	26.2868789	8.8408227	.001447178
697	478864	331373888	26.3058929	8.8450854	.001445087
698	480249	332812557	26.3248932	8.8493440	.001443001
699	481636	334255384	26.3438797	8.8535985	.001440922
700	483025	335702375	26.3628527	8.8578489	.001438849
701	484416	337153536	26.3818119	8.8620952	.001436782
702	485809	338608873	26.4007576	8.8663375	.001434720
703	487204	340068392	26.4196896	8.8705757	.001432663
704	488601	341532099	26.4386081	8.8748099	.001430615
705	490000	343000000	26.4575181	8.8790400	.001428571
706	491401	344472101	26.4764046	8.8832661	.001426534
707	492804	345948408	26.4952826	8.8874882	.001424501
708	494209	347428927	26.5141472	8.8917063	.001422475
709	495616	348913664	26.5329963	8.8959204	.001420455
710	497025	350402625	26.5518361	8.90011804	.001418440
711	498436	351895816	26.5706605	8.9043366	.001416431
712	499849	353393243	26.5894716	8.9085387	.001414427
713	501264	354894912	26.6082694	8.9127369	.001412429
714	502681	356400829	26.6270530	8.9169311	.001410437
715	504100	357911000	26.6458252	8.9211214	.001408451
716	505521	359425431	26.6645833	8.9253078	.001406470
717	506944	360944128	26.6833281	8.9294902	.001404494
718	508369	362467097	26.7020598	8.9336687	.001402525
719	509796	363994344	26.7207784	8.9378433	.001400560
720	511225	365525875	26.7394839	8.9420140	.001398601
721	512656	367061696	26.7581763	8.9461809	.001396648
722	514089	368601813	26.7768557	8.9503438	.001394700
723	515524	370146232	26.7955220	8.9545029	.001392752
724	516961	371694950	26.8141754	8.9586581	.001390821
725	518400	373248000	26.8328157	8.9628095	.001388889
726	519841	374805361	26.8514432	8.9669570	.001386963
727	521284	376367048	26.8700577	8.9711007	.001385042
728	522729	377933067	26.8886593	8.9752406	.001383126
729	524176	379503424	26.9072481	8.9793766	.001381215
730	525625	381078125	26.9258240	8.9835089	.001379310
731	527076	382657176	26.9443872	8.9876373	.001377410
732	528529	384240583	26.9629375	8.9917620	.001375516
733	529984	385828352	26.9814751	8.9958829	.001373626
734	531441	387420489	27.0000000	9.0000000	.001371742
735	532900	389017000	27.0185122	9.0041134	.001369863
736	534361	390617891	27.0370117	9.0082220	.001367989
737	535824	392223168	27.0554985	9.0123288	.001366120
738	537289	393833837	27.0739727	9.0164309	.001364256
739	538756	395449904	27.0924344	9.0205293	.001362398
740	540225	397071375	27.1108884	9.0246239	.001360544
741	541696	398698256	27.1293199	9.0287149	.001358696
742	543169	400330553	27.1477430	9.0328021	.001356852
743	544644	401968272	27.1661554	9.0368857	.001355014
744	546121	403611419	27.1845544	9.0409655	.001353180
745	547600	405260000	27.2029410	9.0450419	.001351351
746	549081	406914021	27.2213152	9.0491142	.001349528
747	550564	408583488	27.2396769	9.0531881	.001347709
748	552049	410258403	27.2580263	9.0572482	.001345895
749	553536	411938784	27.2763634	9.0613008	.001344086

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
745	555025	413498625	27.2946881	9.0658677	.001242288
746	556516	415160936	27.8180006	9.0694220	.001340483
747	558009	416832723	27.3319007	9.0734726	.001338688
748	559504	418508992	27.3495887	9.0775197	.001336898
749	561001	420189749	27.3678644	9.0815631	.001335118
750	562500	421875000	27.3861279	9.0856080	.001333333
751	564001	423564751	27.4043792	9.0896392	.001331553
752	565504	425259008	27.4226184	9.0936719	.001329787
753	567009	426957777	27.4408455	9.0977010	.001328021
754	568516	428661064	27.4590604	9.1017265	.001326260
755	570025	430368875	27.4772632	9.1057485	.001324503
756	571536	432081216	27.4954542	9.1097669	.001322751
757	573049	433798093	27.5136330	9.1137818	.001321004
758	574564	435519512	27.5317998	9.1177931	.001319261
759	576081	437245479	27.5499646	9.1218010	.001317523
760	577600	438976000	27.5680075	9.1258053	.001315789
761	579121	440711081	27.5862284	9.1298061	.001314060
762	580644	442450728	27.6043475	9.1338034	.001312336
763	582169	444194947	27.6224546	9.1377971	.001310616
764	583696	445943744	27.6405499	9.1417874	.001308901
765	585225	447697125	27.6586334	9.1457742	.001307190
766	586756	449455096	27.6767050	9.1497516	.001305483
767	588289	451217663	27.6947648	9.1537375	.001303781
768	589824	452984832	27.7128129	9.1577159	.001302083
769	591361	454756609	27.7308492	9.1616869	.001300389
770	592900	456533000	27.7488739	9.1656565	.001298701
771	594441	458314011	27.7668868	9.1696225	.001297017
772	595984	460099648	27.7848880	9.1735852	.001295337
773	597529	461889917	27.8028775	9.1775445	.001293661
774	599076	463684824	27.8208555	9.1815003	.001291990
775	600625	465484375	27.8388218	9.1854527	.001290323
776	602176	467288576	27.8567766	9.1894018	.001288660
777	603729	469097433	27.8747197	9.1933474	.001287001
778	605284	470910952	27.8926514	9.1972897	.001285347
779	606841	472729139	27.9105715	9.2012286	.001283697
780	608400	474552000	27.9284801	9.2051641	.001282051
781	609961	476379541	27.9463772	9.2090962	.001280410
782	611524	478211768	27.9642620	9.2130250	.001278772
783	613089	480048687	27.9821372	9.2169505	.001277139
784	614656	481890304	28.0000000	9.2208726	.001275510
785	616225	483736625	28.0178615	9.2247914	.001273885
786	617796	485587656	28.0357615	9.2287068	.001272265
787	619369	487443403	28.0536508	9.2326189	.001270648
788	620944	489303872	28.0715377	9.2365277	.001269036
789	622521	491169069	28.0894138	9.2404333	.001267427
790	624100	493039000	28.1069886	9.2443355	.001265823
791	625681	494913671	28.1247222	9.2482344	.001264223
792	627264	496793088	28.1424946	9.2521300	.001262626
793	628849	498677257	28.1602557	9.2560224	.001261034
794	630436	500566184	28.1780056	9.2599114	.001259446
795	632025	502459875	28.1957444	9.2637973	.001257862
796	633616	504358336	28.2134720	9.2676798	.001256281
797	635209	506261573	28.2311884	9.2715592	.001254705
798	636804	508169592	28.2488938	9.2754352	.001253133
799	638401	510082399	28.2665881	9.2793081	.001251564
800	640000	512000000	28.2842712	9.2831777	.001250000
801	641601	513922401	28.3019434	9.2870440	.001248439
802	643204	515849608	28.3196045	9.2909072	.001246888
803	644809	517781627	28.3372546	9.2947671	.001245339
804	646416	519718464	28.3549038	9.2986239	.001243791
805	648025	521660125	28.3725219	9.3024775	.001242246
806	649636	523606616	28.3901391	9.3063278	.001240706

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
807	651249	525557948	28.4077454	9.3101750	.001239157
808	652864	527514112	28.4253408	9.3140190	.001237624
809	654481	529475129	28.4429253	9.3178599	.001236094
810	656100	531441000	28.4604989	9.3216975	.001234568
811	657721	533411731	28.4780617	9.3255320	.001233046
812	659344	535387328	28.4956137	9.3293634	.001231527
813	660969	537367797	28.5131549	9.3331916	.001230012
814	662596	539353144	28.5306852	9.3370167	.001228501
815	664223	541343375	28.5482048	9.3408386	.001226994
816	665856	543338496	28.5657137	9.3446575	.001225490
817	667489	545338513	28.5832119	9.3484731	.001223980
818	669124	547343432	28.6006993	9.3522857	.001222494
819	670761	549353259	28.6181760	9.3560952	.001221001
820	672400	551368000	28.6356421	9.3599016	.001219512
821	674041	553387661	28.6530976	9.3637049	.001218027
822	675684	555412248	28.6705424	9.3675051	.001216545
823	677329	557441767	28.6879766	9.3713022	.001215067
824	678976	559476224	28.7054002	9.3750963	.001213592
825	680625	561515625	28.7228132	9.3788873	.001212121
826	682276	563559976	28.7402157	9.3826752	.001210654
827	683929	565609283	28.7576077	9.3864600	.001209190
828	685584	567663552	28.7749891	9.3902419	.001207729
829	687241	569722789	28.7923601	9.3940206	.001206273
830	688900	571787000	28.8097206	9.3977964	.001204819
831	690561	573856191	28.8270706	9.4015691	.001203369
832	692224	575930368	28.8444102	9.4053387	.001201923
833	693889	578009537	28.8617394	9.4091054	.001200480
834	695556	580093704	28.8790582	9.4128690	.001199041
835	697225	582182875	28.8963666	9.4166297	.001197605
836	698896	584277056	28.9136646	9.4203873	.001196172
837	700569	586376253	28.9309523	9.4241420	.001194743
838	702244	588480472	28.9482237	9.4278936	.001193317
839	703921	590589719	28.9654967	9.4316423	.001191895
840	705600	592704000	28.9827535	9.4353880	.001190476
841	707281	594823321	29.0000000	9.4391307	.001189061
842	708964	596947688	29.0172303	9.4428704	.001187648
843	710649	599077107	29.0344623	9.4466072	.001186240
844	712336	601211584	29.0516781	9.4503410	.001184834
845	714025	603351125	29.0688837	9.4540719	.001183432
846	715716	605495736	29.0860791	9.4577999	.001182033
847	717409	607645423	29.1032644	9.4615249	.001180639
848	719104	609800192	29.1204396	9.4652470	.001179245
849	720801	611960049	29.1376046	9.4689661	.001177856
850	722500	614125000	29.1547595	9.4726824	.001176471
851	724201	616295051	29.1719043	9.4763957	.001175088
852	725904	618470208	29.1890390	9.4801061	.001173700
853	727609	620650477	29.2061637	9.4838136	.001172333
854	729316	622835864	29.2232784	9.4875182	.001170960
855	731025	625026375	29.2403830	9.4912200	.001169591
856	732736	627222016	29.2574777	9.4949188	.001168224
857	734449	629422793	29.2745623	9.4986147	.001166861
858	736164	631628712	29.2916370	9.5023078	.001165501
859	737881	633839779	29.3087018	9.5059980	.001164144
860	739600	636056000	29.3257566	9.5096854	.001162791
861	741321	638277381	29.3428015	9.5133699	.001161440
862	743044	640503928	29.3598365	9.5170515	.001160093
863	744769	642735647	29.3768616	9.5207303	.001158749
864	746496	644972544	29.3938769	9.5244063	.001157407
865	748225	647214625	29.4108823	9.5280794	.001156069
866	749956	649461896	29.4278779	9.5317497	.001154734
867	751689	651714363	29.4448637	9.5354172	.001153403
868	753424	653972032	29.4618397	9.5390818	.001152074

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
869	755161	656234909	29.4788059	9.5427437	.001150748
870	756900	658508000	29.4957624	9.5464027	.001149425
871	758641	660776811	29.5127091	9.5500589	.001148106
872	760384	663054848	29.5296461	9.5537123	.001146789
873	762129	665338617	29.5465734	9.5573630	.001145475
874	763876	667627624	29.5634910	9.5610108	.001144165
875	765625	669921875	29.5803989	9.5646559	.001142857
876	767376	672221376	29.5972972	9.5682982	.001141553
877	769129	674526133	29.6141858	9.5719377	.001140251
878	770884	676836152	29.6310648	9.5755745	.001138952
879	772641	679151439	29.6479342	9.5792085	.001137656
880	774400	681472000	29.6647939	9.5828397	.001136364
881	776161	683797841	29.6816442	9.5864682	.001135074
882	777924	686128968	29.6984848	9.5900939	.001133787
883	779689	688465387	29.7153159	9.5937169	.001132503
884	781456	690807104	29.7321375	9.5973373	.001131222
885	783225	693154125	29.7489496	9.6009548	.001129944
886	784996	695506456	29.7657521	9.6045696	.001128668
887	786769	697864103	29.7825452	9.6081817	.001127396
888	788544	700227072	29.7993239	9.6117911	.001126126
889	790321	702595369	29.8161030	9.6153977	.001124859
890	792100	704969000	29.8328678	9.6190017	.001123596
891	793881	707347971	29.8496231	9.6226030	.001122334
892	795664	709732288	29.8663690	9.6262016	.001121076
893	797449	712121957	29.8831056	9.6297975	.001119821
894	799236	714516984	29.8998328	9.6333907	.001118568
895	801025	716917375	29.9165506	9.6369812	.001117318
896	802816	719323136	29.9332591	9.6405690	.001116071
897	804609	721734273	29.9499583	9.6441542	.001114827
898	806404	724150792	29.9666481	9.6477367	.001113586
899	808201	726572699	29.9833237	9.6513166	.001112347
900	810000	729000000	30.0000000	9.6548938	.001111111
901	811801	731432701	30.0166620	9.6584684	.001109878
902	813604	733870808	30.0333148	9.6620408	.001108647
903	815409	736314327	30.0499584	9.6656096	.001107420
904	817216	738763264	30.0665928	9.6691762	.001106195
905	819025	741217625	30.0832179	9.6727403	.001104972
906	820836	743677416	30.0998339	9.6763017	.001103753
907	822649	746142643	30.1164407	9.6798604	.001102536
908	824464	748613312	30.1330383	9.6834166	.001101322
909	826281	751089429	30.1496269	9.6869701	.001100110
910	828100	753571000	30.1662063	9.6905211	.001098901
911	829921	756058031	30.1827765	9.6940694	.001097695
912	831744	758550528	30.1993377	9.6976151	.001096491
913	833569	761048497	30.2158899	9.7011583	.001095290
914	835396	763551944	30.2324329	9.7046989	.001094092
915	837225	766060875	30.2489669	9.7082369	.001092896
916	839056	768575296	30.2654919	9.7117723	.001091703
917	840889	771095213	30.2820079	9.7153061	.001090513
918	842724	773620632	30.2985148	9.7188354	.001089325
919	844561	776151559	30.3150128	9.7223631	.001088139
920	846400	778688000	30.3315018	9.7258883	.001086957
921	848241	781229961	30.3479818	9.7294109	.001085778
922	850084	783777448	30.3644529	9.7329309	.001084599
923	851929	786330467	30.3809151	9.7364484	.001083423
924	853776	788889024	30.3973683	9.7399634	.001082251
925	855625	791453125	30.4138127	9.7434758	.001081081
926	857476	794022776	30.4302481	9.7469857	.001079914
927	859329	796597983	30.4466747	9.7504930	.001078749
928	861184	799178752	30.4630924	9.7539979	.001077586
929	863041	801765089	30.4795013	9.7575002	.001076426
930	864900	804357000	30.4959014	9.7610001	.001075269

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
931	866761	806954491	30.5122926	9.7644974	.001074114
932	868624	809557568	30.5286750	9.7679922	.001072961
933	870489	812166237	30.5450487	9.7714845	.001071811
934	872356	814786504	30.5614186	9.7749743	.001070664
935	874225	817400375	30.5777697	9.7784616	.001069519
936	876096	820025856	30.5941171	9.7819466	.001068376
937	877969	822650653	30.6104557	9.7854288	.001067236
938	879844	825293672	30.6267857	9.7889087	.001066098
939	881721	827936019	30.6431069	9.7923861	.001064963
940	883600	830584000	30.6594194	9.7958611	.001063830
941	885481	833237621	30.6757233	9.7993336	.001062699
942	887364	835896888	30.6920185	9.8028036	.001061571
943	889249	838561807	30.7083051	9.8062711	.001060445
944	891136	841232384	30.7245830	9.8097362	.001059322
945	893025	843908625	30.7408523	9.8131989	.001058201
946	894916	846590536	30.7571130	9.8166591	.001057082
947	896809	849278123	30.7733651	9.8201169	.001055966
948	898704	851971392	30.7896086	9.8235723	.001054852
949	900601	854670349	30.8058436	9.8270252	.001053741
950	902500	857375000	30.8220700	9.8304757	.001052632
951	904401	860085351	30.8382879	9.8339238	.001051525
952	906304	862801408	30.8544972	9.8373695	.001050420
953	908209	865523177	30.8706981	9.8408127	.001049318
954	910116	868250664	30.8868904	9.8442536	.001048218
955	912025	870983875	30.9030743	9.8476920	.001047120
956	913936	873722816	30.9192497	9.8511280	.001046025
957	915849	876467493	30.9354166	9.8545617	.001044932
958	917764	879217912	30.9515751	9.8579929	.001043841
959	919681	881974079	30.9677251	9.8614218	.001042753
960	921600	884736000	30.9838668	9.8648483	.001041667
961	923521	887503681	31.0000000	9.8682724	.001040583
962	925444	£90277128	31.0161248	9.8716941	.001039501
963	927369	£93056347	31.0322413	9.8751135	.001038422
964	929296	£95841344	31.0483494	9.8785305	.001037344
965	931225	£98632125	31.0644491	9.8819451	.001036269
966	933156	901428696	31.0805405	9.8853574	.001035197
967	935089	904231063	31.0966236	9.8887673	.001034126
968	937024	907039232	31.1126984	9.8921749	.001033058
969	938961	909853209	31.1287648	9.8955801	.001031992
970	940900	912673000	31.1448230	9.8989830	.001030928
971	942841	915498611	31.1608729	9.9023835	.001029866
972	944784	918330048	31.1769145	9.9057817	.001028807
973	946729	921167317	31.1929479	9.9091776	.001027749
974	948676	924010424	31.2089731	9.9125712	.001026694
975	950625	926859375	31.2249900	9.9159624	.001025641
976	952576	929714176	31.2409987	9.9193513	.001024590
977	954529	932574833	31.2569992	9.9227379	.001023541
978	956484	935441352	31.2729915	9.9261222	.001022495
979	958441	938313739	31.2889757	9.9295042	.001021450
980	960400	941192000	31.3049517	9.9328839	.001020408
981	962361	944076141	31.3209195	9.9362613	.001019368
982	964324	946966168	31.3368773	9.9396363	.001018330
983	966289	949862087	31.3528308	9.9430092	.001017294
984	968256	952763904	31.3687743	9.9463797	.001016260
985	970225	955671625	31.3847097	9.9497479	.001015228
986	972196	958585256	31.4006369	9.9531138	.001014199
987	974169	961504803	31.4165561	9.9564775	.001013171
988	976144	964430272	31.4324673	9.9598389	.001012146
989	978121	967361669	31.4483704	9.9631981	.001011122
990	980100	970299000	31.4642654	9.9665549	.001010101
991	982081	973242271	31.4801525	9.9699095	.001009082
992	984064	976191488	31.4960315	9.9732619	.001008065

TABLE VIII.—Continued.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
993	986049	979146657	31.5119025	9.9766120	.001007049
994	988036	982107784	31.5277655	9.9799599	.001006036
995	990025	985074875	31.5436206	9.9833055	.001005025
996	992010	988047936	31.5594677	9.9866488	.001004016
997	994000	991026973	31.5753068	9.9899900	.001003009
998	996004	994011992	31.5911880	9.9933289	.001002004
999	998001	997002099	31.6069613	9.9966656	.001001001
1000	1000000	1000000000	31.6227766	10.0000000	.001000000
1001	1002001	1003003001	31.6385840	10.0083322	.0009990010
1002	1004004	1006012008	31.6543836	10.0066622	.0009980040
1003	1006009	1009027027	31.6701752	10.0099899	.0009970090
1004	1008016	1012448064	31.6859590	10.0133155	.0009960159
1005	1010025	1015075125	31.7017349	10.0166389	.0009950249
1006	1012036	1018108216	31.7175080	10.0199601	.0009940358
1007	1014049	1021147343	31.7332683	10.0232791	.0009930487
1008	1016064	1024192512	31.7490157	10.0265958	.0009920635
1009	1018081	1027243729	31.7647608	10.0299104	.0009910803
1010	1020100	1030301000	31.7804972	10.0332228	.0009900990
1011	1022121	1033364331	31.7962262	10.0365330	.0009891197
1012	1024144	1036433723	31.8119474	10.0398410	.0009881423
1013	1026169	1039509197	31.8276609	10.0431469	.0009871668
1014	1028196	1042590744	31.8433666	10.0464506	.0009861933
1015	1030225	1045678375	31.8590646	10.0497521	.0009852217
1016	1032256	1048772096	31.8747549	10.0530514	.0009842520
1017	1034289	1051871913	31.8904374	10.0563485	.0009832842
1018	1036324	1054977832	31.9061123	10.0596435	.0009823183
1019	1038361	1058089859	31.9217794	10.0629364	.0009813543
1020	1040400	1061208000	31.9374388	10.0662271	.0009803922
1021	1042441	1064332261	31.9530906	10.0695156	.0009794319
1022	1044484	1067462648	31.9687347	10.0728020	.0009784736
1023	1046529	1070599167	31.9843712	10.0760863	.0009775171
1024	1048576	1073741824	32.0000000	10.0793684	.0009765625
1025	1050625	1076890625	32.0156212	10.0826484	.0009756098
1026	1052676	1080045576	32.0312348	10.0859262	.0009746589
1027	1054729	1083206683	32.0468407	10.0892019	.0009737098
1028	1056784	1086373932	32.0624391	10.0924755	.0009727626
1029	1058841	1089547389	32.0780298	10.0957469	.0009718173
1030	1060900	1092727000	32.0936131	10.0990163	.0009708738
1031	1062961	1095912791	32.1091887	10.1022835	.0009699321
1032	1065024	1099104768	32.1247568	10.1055487	.0009690922
1033	1067089	1102302937	32.1403173	10.1088117	.0009682542
1034	1069156	1105507304	32.1558704	10.1120726	.0009674180
1035	1071225	1108717875	32.1714159	10.1153314	.0009665836
1036	1073296	1111934656	32.1869539	10.1185882	.0009657510
1037	1075369	1115157653	32.2024844	10.1218428	.0009649202
1038	1077444	1118386972	32.2180074	10.1250953	.0009640911
1039	1079521	1121622319	32.2335229	10.1283457	.0009632639
1040	1081600	1124864000	32.2490310	10.1315941	.0009624385
1041	1083681	1128111921	32.2645316	10.1348403	.0009616148
1042	1085764	1131366088	32.2800248	10.1380845	.0009607929
1043	1087849	1134626507	32.2955105	10.1413266	.0009599738
1044	1089936	1137893184	32.3109888	10.1445667	.0009591544
1045	1092025	1141166125	32.3264598	10.1478047	.0009583378
1046	1094116	1144445336	32.3419233	10.1510406	.0009575229
1047	1096209	1147730823	32.3573794	10.1542744	.0009567098
1048	1098304	1151022592	32.3728281	10.1575062	.0009558985
1049	1100401	1154320649	32.3882695	10.1607359	.0009550888
1050	1102500	1157625000	32.4037035	10.1639636	.0009542810
1051	1104601	1160935651	32.4191301	10.1671893	.0009534748
1052	1106704	1164252608	32.4345495	10.1704129	.0009526703
1053	1108809	1167575877	32.4499615	10.1736344	.0009518676
1054	1110916	1170905464	32.4653662	10.1768539	.0009510666

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
100	00000	00043	00087	00130	00173	00217	00260	00303	00346	00389
1	0432	0475	0518	0561	0604	0647	0689	0732	0775	0817
2	0860	0903	0945	0988	1030	1072	1115	1157	1199	1242
3	1284	1326	1368	1410	1452	1494	1536	1578	1620	1662
4	1703	1745	1787	1828	1870	1912	1953	1995	2036	2078
5	2119	2160	2202	2243	2284	2325	2366	2407	2449	2490
6	2531	2572	2612	2653	2694	2735	2776	2816	2857	2898
7	2938	2979	3019	3060	3100	3141	3181	3222	3262	3302
8	3342	3383	3423	3463	3503	3543	3583	3623	3663	3703
9	3743	3782	3822	3862	3902	3941	3981	4021	4060	4100
110	04139	04179	04218	04258	04297	04336	04376	04415	04454	04493
1	4532	4571	4610	4650	4689	4727	4766	4805	4844	4883
2	4922	4961	4999	5038	5077	5115	5154	5192	5231	5269
3	5308	5346	5385	5423	5461	5500	5538	5576	5614	5652
4	5690	5729	5767	5805	5843	5881	5918	5956	5994	6032
5	6070	6108	6145	6183	6221	6258	6296	6333	6371	6408
6	6446	6483	6521	6558	6595	6633	6670	6707	6744	6781
7	6819	6856	6893	6930	6967	7004	7041	7078	7115	7151
8	7188	7225	7262	7298	7335	7372	7408	7445	7482	7518
9	7555	7591	7628	7664	7700	7737	7773	7809	7846	7882
120	07918	07954	07990	08027	08063	08099	08135	08171	08207	08243
1	8279	8314	8350	8386	8422	8458	8493	8529	8565	8600
2	8636	8672	8707	8743	8778	8814	8849	8884	8920	8955
3	8991	9026	9061	9096	9132	9167	9202	9237	9272	9307
4	9342	9377	9412	9447	9482	9517	9552	9587	9621	9656
5	9691	9726	9760	9795	9830	9864	9899	9934	9968	10003
6	10037	10072	10106	10140	10175	10209	10243	10278	10312	0346
7	0380	0415	0449	0483	0517	0551	0585	0619	0653	0687
8	0721	0755	0789	0823	0857	0890	0924	0958	0992	1025
9	1059	1093	1126	1160	1193	1227	1261	1294	1327	1361
130	11394	11428	11461	11494	11528	11561	11594	11628	11661	11694
1	1727	1760	1793	1826	1860	1893	1926	1959	1992	2024
2	2057	2090	2123	2156	2189	2222	2254	2287	2320	2352
3	2385	2418	2450	2483	2516	2548	2581	2613	2646	2678
4	2710	2743	2775	2808	2840	2872	2905	2937	2969	3001
5	3033	3066	3098	3130	3162	3194	3226	3258	3290	3322
6	3354	3386	3418	3450	3481	3513	3545	3577	3609	3640
7	3672	3704	3735	3767	3799	3830	3862	3893	3925	3956
8	3988	4019	4051	4082	4114	4145	4176	4208	4239	4270
9	4301	4333	4364	4395	4426	4457	4489	4520	4551	4582
140	14613	14644	14675	14706	14737	14768	14799	14829	14860	14891
1	4922	4953	4983	5014	5045	5076	5106	5137	5168	5198
2	5229	5259	5290	5320	5351	5381	5412	5442	5473	5503
3	5534	5564	5594	5625	5655	5685	5715	5746	5776	5806
4	5836	5866	5897	5927	5957	5987	6017	6047	6077	6107
5	6137	6167	6197	6227	6256	6286	6316	6346	6376	6406
6	6435	6465	6495	6524	6554	6584	6613	6643	6673	6702
7	6732	6761	6791	6820	6850	6879	6909	6938	6967	6997
8	7026	7056	7085	7114	7143	7173	7202	7231	7260	7289
9	7319	7348	7377	7406	7435	7464	7493	7522	7551	7580
150	17609	17638	17667	17696	17725	17754	17782	17811	17840	17869

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
150	17609	17638	17667	17696	17725	17754	17782	17811	17840	17869
1	7898	7926	7955	7984	8013	8041	8070	8099	8127	8156
2	8184	8213	8241	8270	8298	8327	8355	8384	8412	8441
3	8469	8498	8526	8554	8583	8611	8639	8667	8696	8724
4	8752	8780	8808	8837	8865	8893	8921	8949	8977	9005
5	9033	9061	9089	9117	9145	9173	9201	9229	9257	9285
6	9312	9340	9368	9396	9424	9451	9479	9507	9535	9562
7	9590	9618	9645	9673	9700	9728	9756	9783	9811	9838
8	9866	9893	9921	9948	9976	20003	20030	20058	20085	20112
9	20140	20167	20194	20222	20249	0276	0303	0330	0358	0385
160	20412	20439	20466	20493	20520	20548	20575	20602	20629	20656
1	0683	0710	0737	0763	0790	0817	0844	0871	0898	0925
2	0952	0978	1005	1032	1059	1085	1112	1139	1165	1192
3	1219	1245	1272	1299	1325	1352	1378	1405	1431	1458
4	1484	1511	1537	1564	1590	1617	1643	1669	1696	1722
5	1748	1775	1801	1827	1854	1880	1906	1932	1958	1985
6	2011	2037	2063	2089	2115	2141	2167	2194	2220	2246
7	2272	2298	2324	2350	2376	2401	2427	2453	2479	2505
8	2531	2557	2583	2608	2634	2660	2686	2712	2737	2763
9	2789	2814	2840	2866	2891	2917	2943	2968	2994	3019
170	23045	23070	23096	23121	23147	23172	23198	23223	23249	23274
1	3300	3325	3350	3376	3401	3426	3452	3477	3502	3528
2	3553	3578	3603	3629	3654	3679	3704	3729	3754	3779
3	3805	3830	3855	3880	3905	3930	3955	3980	4005	4030
4	4055	4080	4105	4130	4155	4180	4204	4229	4254	4279
5	4304	4329	4353	4378	4403	4428	4452	4477	4502	4527
6	4551	4576	4601	4625	4650	4674	4699	4724	4748	4773
7	4797	4822	4846	4871	4895	4920	4944	4969	4993	5018
8	5042	5066	5091	5115	5139	5164	5188	5212	5237	5261
9	5285	5310	5334	5358	5382	5406	5431	5455	5479	5503
180	25527	25551	25575	25600	25624	25648	25672	25696	25720	25744
1	5768	5792	5816	5840	5864	5888	5912	5935	5959	5983
2	6007	6031	6055	6079	6102	6126	6150	6174	6198	6221
3	6245	6269	6293	6316	6340	6364	6387	6411	6435	6458
4	6482	6505	6529	6553	6576	6600	6623	6647	6670	6694
5	6717	6741	6764	6788	6811	6834	6858	6881	6905	6928
6	6951	6975	6998	7021	7045	7068	7091	7114	7138	7161
7	7184	7207	7231	7254	7277	7300	7323	7346	7370	7393
8	7416	7439	7462	7485	7508	7531	7554	7577	7600	7623
9	7646	7669	7692	7715	7738	7761	7784	7807	7830	7852
190	27875	27898	27921	27944	27967	27989	28012	28035	28058	28081
1	8103	8126	8149	8171	8194	8217	8240	8262	8285	8307
2	8330	8353	8375	8398	8421	8443	8466	8488	8511	8533
3	8556	8578	8601	8623	8646	8668	8691	8713	8735	8758
4	8780	8803	8825	8847	8870	8892	8914	8937	8959	8981
5	9003	9026	9048	9070	9092	9115	9137	9159	9181	9203
6	9226	9248	9270	9292	9314	9336	9358	9380	9403	9425
7	9447	9469	9491	9513	9535	9557	9579	9601	9623	9645
8	9667	9688	9710	9732	9754	9776	9798	9820	9842	9863
9	9885	9907	9929	9951	9973	9994	30016	30038	30060	30081
200	30103	30125	30146	30168	30190	30211	30233	30255	30276	30298

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
200	30103	30125	30146	30168	30190	30211	30233	30255	30276	30298
1	0320	0341	0363	0384	0406	0428	0449	0471	0492	0514
2	0535	0557	0578	0600	0621	0643	0664	0685	0707	0728
3	0750	0771	0792	0814	0835	0856	0878	0899	0920	0942
4	0963	0984	1006	1027	1048	1069	1091	1112	1133	1154
5	1175	1197	1218	1239	1260	1281	1302	1323	1345	1366
6	1387	1408	1429	1450	1471	1492	1513	1534	1555	1576
7	1597	1618	1639	1660	1681	1702	1723	1744	1765	1785
8	1806	1827	1848	1869	1890	1911	1931	1952	1973	1994
9	2015	2035	2056	2077	2098	2118	2139	2160	2181	2201
210	32222	32243	32263	32284	32305	32325	32346	32366	32387	32408
1	2428	2449	2469	2490	2510	2531	2552	2572	2593	2613
2	2634	2654	2675	2695	2715	2736	2756	2777	2797	2818
3	2838	2858	2879	2899	2919	2940	2960	2980	3001	3021
4	3041	3062	3082	3102	3122	3143	3163	3183	3203	3224
5	3244	3264	3284	3304	3325	3345	3365	3385	3405	3425
6	3445	3465	3486	3506	3526	3546	3566	3586	3606	3626
7	3646	3666	3686	3706	3726	3746	3766	3786	3806	3826
8	3846	3866	3885	3905	3925	3945	3965	3985	4005	4025
9	4044	4064	4084	4104	4124	4143	4163	4183	4203	4223
220	34242	34262	34282	34301	34321	34341	34361	34380	34400	34420
1	4439	4459	4479	4498	4518	4537	4557	4577	4596	4616
2	4635	4655	4674	4694	4713	4733	4753	4772	4792	4811
3	4830	4850	4869	4889	4908	4928	4947	4967	4986	5005
4	5025	5044	5064	5083	5102	5122	5141	5160	5180	5199
5	5218	5238	5257	5276	5295	5315	5334	5353	5372	5392
6	5411	5430	5449	5468	5488	5507	5526	5545	5564	5583
7	5603	5622	5641	5660	5679	5698	5717	5736	5755	5774
8	5793	5813	5832	5851	5870	5889	5908	5927	5946	5965
9	5984	6003	6021	6040	6059	6078	6097	6116	6135	6154
230	36173	36192	36211	36229	36248	36267	36286	36305	36324	36342
1	6361	6380	6399	6418	6436	6455	6474	6493	6511	6530
2	6549	6568	6586	6605	6624	6642	6661	6680	6698	6717
3	6736	6754	6773	6791	6810	6829	6847	6866	6884	6903
4	6922	6940	6959	6977	6996	7014	7033	7051	7070	7088
5	7107	7125	7144	7162	7181	7199	7218	7236	7254	7273
6	7291	7310	7328	7346	7365	7383	7401	7420	7438	7457
7	7475	7493	7511	7530	7548	7566	7585	7603	7621	7639
8	7658	7676	7694	7712	7731	7749	7767	7785	7803	7822
9	7840	7858	7876	7894	7912	7931	7949	7967	7985	8003
240	38021	38039	38057	38075	38093	38112	38130	38148	38166	38184
1	8202	8220	8238	8256	8274	8292	8310	8328	8346	8364
2	8382	8399	8417	8435	8453	8471	8489	8507	8525	8543
3	8561	8578	8596	8614	8632	8650	8668	8686	8703	8721
4	8739	8757	8775	8792	8810	8828	8846	8863	8881	8899
5	8917	8934	8952	8970	8987	9005	9023	9041	9058	9076
6	9094	9111	9129	9146	9164	9182	9199	9217	9235	9252
7	9270	9287	9305	9322	9340	9358	9375	9393	9410	9428
8	9445	9463	9480	9498	9515	9533	9550	9568	9585	9602
9	9620	9637	9655	9672	9690	9707	9724	9742	9759	9777
250	39794	39811	39829	39846	39863	39881	39898	39915	39933	39950

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
250	39794	39811	39829	39846	39863	39881	39898	39915	39933	39950
1	9967	9985	40002	40019	40037	40054	40071	40088	40106	40123
2	40140	40157	0175	0192	0209	0226	0243	0261	0278	0295
3	0312	0329	0346	0364	0381	0398	0415	0432	0449	0466
4	0483	0500	0518	0535	0552	0569	0586	0603	0620	0637
5	0654	0671	0688	0705	0722	0739	0756	0773	0790	0807
6	0824	0841	0858	0875	0892	0909	0926	0943	0960	0976
7	0993	1010	1027	1044	1061	1078	1095	1111	1128	1145
8	1162	1179	1196	1212	1229	1246	1263	1280	1296	1313
9	1330	1347	1363	1380	1397	1414	1430	1447	1464	1481
260	41497	41514	41531	41547	41564	41581	41597	41614	41631	41647
1	1664	1681	1697	1714	1731	1747	1764	1780	1797	1814
2	1830	1847	1863	1880	1896	1913	1929	1946	1963	1979
3	1996	2012	2029	2045	2062	2078	2095	2111	2127	2144
4	2160	2177	2193	2210	2226	2243	2259	2275	2292	2308
5	2325	2341	2357	2374	2390	2406	2423	2439	2455	2472
6	2488	2504	2521	2537	2553	2570	2586	2602	2619	2635
7	2651	2667	2684	2700	2716	2732	2749	2765	2781	2797
8	2813	2830	2846	2862	2878	2894	2911	2927	2943	2959
9	2975	2991	3008	3024	3040	3056	3072	3088	3104	3120
270	43136	43152	43169	43185	43201	43217	43233	43249	43265	43281
1	3297	3313	3329	3345	3361	3377	3393	3409	3425	3441
2	3457	3473	3489	3505	3521	3537	3553	3569	3584	3600
3	3616	3632	3648	3664	3680	3696	3712	3727	3743	3759
4	3775	3791	3807	3823	3838	3854	3870	3886	3902	3917
5	3933	3949	3965	3981	3996	4012	4028	4044	4059	4075
6	4091	4107	4122	4138	4154	4170	4185	4201	4217	4232
7	4248	4264	4279	4295	4311	4326	4342	4358	4373	4389
8	4404	4420	4436	4451	4467	4483	4498	4514	4529	4545
9	4560	4576	4592	4607	4623	4638	4654	4669	4685	4700
280	44716	44731	44747	44762	44778	44793	44809	44824	44840	44855
1	4871	4886	4902	4917	4932	4948	4963	4979	4994	5010
2	5025	5040	5056	5071	5086	5102	5117	5133	5148	5163
3	5179	5194	5209	5225	5240	5255	5271	5286	5301	5317
4	5332	5347	5362	5378	5393	5408	5423	5439	5454	5469
5	5484	5500	5515	5530	5545	5561	5576	5591	5606	5621
6	5637	5652	5667	5682	5697	5712	5728	5743	5758	5773
7	5788	5803	5818	5834	5849	5864	5879	5894	5909	5924
8	5939	5954	5969	5984	6000	6015	6030	6045	6060	6075
9	6090	6105	6120	6135	6150	6165	6180	6195	6210	6225
290	46240	46255	46270	46285	46300	46315	46330	46345	46359	46374
1	6389	6404	6419	6434	6449	6464	6479	6494	6509	6523
2	6538	6553	6568	6583	6598	6613	6627	6642	6657	6672
3	6687	6702	6716	6731	6746	6761	6776	6790	6805	6820
4	6835	6850	6864	6879	6894	6909	6923	6938	6953	6967
5	6982	6997	7012	7026	7041	7056	7070	7085	7100	7114
6	7129	7144	7159	7173	7188	7202	7217	7232	7246	7261
7	7276	7290	7305	7319	7334	7349	7363	7378	7392	7407
8	7422	7436	7451	7465	7480	7494	7509	7524	7538	7553
9	7567	7582	7596	7611	7625	7640	7654	7669	7683	7698
300	47712	47727	47741	47756	47770	47784	47799	47813	47828	47842

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
300	47712	47727	47741	47756	47770	47784	47799	47813	47828	47842
1	7857	7871	7885	7900	7914	7929	7943	7958	7972	7986
2	8001	8015	8029	8044	8058	8073	8087	8101	8116	8130
3	8144	8159	8173	8187	8202	8216	8230	8244	8259	8273
4	8287	8302	8316	8330	8344	8359	8373	8387	8401	8416
5	8430	8444	8458	8473	8487	8501	8515	8530	8544	8558
6	8572	8586	8601	8615	8629	8643	8657	8671	8686	8700
7	8714	8728	8742	8756	8770	8785	8799	8813	8827	8841
8	8855	8869	8883	8897	8911	8926	8940	8954	8968	8982
9	8996	9010	9024	9038	9052	9066	9080	9094	9108	9122
310	49136	49150	49164	49178	49192	49206	49220	49234	49248	49262
1	9276	9290	9304	9318	9332	9346	9360	9374	9388	9402
2	9415	9429	9443	9457	9471	9485	9499	9513	9527	9541
3	9554	9568	9582	9596	9610	9624	9638	9651	9665	9679
4	9693	9707	9721	9734	9748	9762	9776	9790	9803	9817
5	9831	9845	9859	9872	9886	9900	9914	9927	9941	9955
6	9969	9982	9996	50010	50024	50037	50051	50065	50079	50092
7	50106	50120	50133	0147	0161	0174	0188	0202	0215	0229
8	0243	0256	0270	0284	0297	0311	0325	0338	0352	0365
9	0379	0393	0406	0420	0433	0447	0461	0474	0488	0501
320	50515	50529	50542	50556	50569	50583	50596	50610	50623	50637
1	0651	0664	0678	0691	0705	0718	0732	0745	0759	0772
2	0786	0799	0813	0826	0840	0853	0866	0880	0893	0907
3	0920	0934	0947	0961	0974	0987	1001	1014	1028	1041
4	1055	1068	1081	1095	1108	1121	1135	1148	1162	1175
5	1188	1202	1215	1228	1242	1255	1268	1282	1295	1308
6	1322	1335	1348	1362	1375	1388	1402	1415	1428	1441
7	1455	1468	1481	1495	1508	1521	1534	1548	1561	1574
8	1587	1601	1614	1627	1640	1654	1667	1680	1693	1706
9	1720	1733	1746	1759	1772	1786	1799	1812	1825	1838
330	51851	51865	51878	51891	51904	51917	51930	51943	51957	51970
1	1983	1996	2009	2022	2035	2048	2061	2075	2088	2101
2	2114	2127	2140	2153	2166	2179	2192	2205	2218	2231
3	2244	2257	2270	2284	2297	2310	2323	2336	2349	2362
4	2375	2388	2401	2414	2427	2440	2453	2466	2479	2492
5	2504	2517	2530	2543	2556	2569	2582	2595	2608	2621
6	2634	2647	2660	2673	2686	2699	2711	2724	2737	2750
7	2763	2776	2789	2802	2815	2827	2840	2853	2866	2879
8	2892	2905	2917	2930	2943	2956	2969	2982	2994	3007
9	3020	3033	3046	3058	3071	3084	3097	3110	3122	3135
340	53148	53161	53173	53186	53199	53212	53224	53237	53250	53263
1	3275	3288	3301	3314	3326	3339	3352	3364	3377	3390
2	3403	3415	3428	3441	3453	3466	3479	3491	3504	3517
3	3529	3542	3555	3567	3580	3593	3605	3618	3631	3643
4	3656	3668	3681	3694	3706	3719	3732	3744	3757	3769
5	3782	3794	3807	3820	3832	3845	3857	3870	3882	3895
6	3908	3920	3933	3945	3958	3970	3983	3995	4008	4020
7	4033	4045	4058	4070	4083	4095	4108	4120	4133	4145
8	4158	4170	4183	4195	4208	4220	4233	4245	4258	4270
9	4283	4295	4307	4320	4332	4345	4357	4370	4382	4394
350	54407	54419	54432	54444	54456	54469	54481	54494	54506	54518

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
350	54407	54419	54432	54444	54456	54469	54481	54494	54506	54518
1	4531	4543	4555	4568	4580	4593	4605	4617	4630	4642
2	4654	4667	4679	4691	4704	4716	4728	4741	4753	4765
3	4777	4790	4802	4814	4827	4839	4851	4864	4876	4888
4	4900	4913	4925	4937	4949	4962	4974	4986	4998	5011
5	5023	5035	5047	5060	5072	5084	5096	5108	5121	5133
6	5145	5157	5169	5182	5194	5206	5218	5230	5242	5255
7	5267	5279	5291	5303	5315	5328	5340	5352	5364	5376
8	5388	5400	5413	5425	5437	5449	5461	5473	5485	5497
9	5509	5522	5534	5546	5558	5570	5582	5594	5606	5618
360	55630	55642	55654	55666	55678	55691	55703	55715	55727	55739
1	5751	5763	5775	5787	5799	5811	5823	5835	5847	5859
2	5871	5883	5895	5907	5919	5931	5943	5955	5967	5979
3	5991	6003	6015	6027	6038	6050	6062	6074	6086	6098
4	6110	6122	6134	6146	6158	6170	6182	6194	6205	6217
5	6229	6241	6253	6265	6277	6289	6301	6312	6324	6336
6	6348	6360	6372	6384	6396	6407	6419	6431	6443	6455
7	6467	6478	6490	6502	6514	6526	6538	6549	6561	6573
8	6585	6597	6608	6620	6632	6644	6656	6667	6679	6691
9	6703	6714	6726	6738	6750	6761	6773	6785	6797	6808
370	56820	56832	56844	56855	56867	56879	56891	56902	56914	56926
1	6937	6949	6961	6972	6984	6996	7008	7019	7031	7043
2	7054	7066	7078	7089	7101	7113	7124	7136	7148	7159
3	7171	7183	7194	7206	7217	7229	7241	7252	7264	7276
4	7287	7299	7310	7322	7334	7345	7357	7368	7380	7392
5	7403	7415	7426	7438	7449	7461	7473	7484	7496	7507
6	7519	7530	7542	7553	7565	7576	7588	7600	7611	7623
7	7634	7646	7657	7669	7680	7692	7703	7715	7726	7738
8	7749	7761	7772	7784	7795	7807	7818	7830	7841	7852
9	7864	7875	7887	7898	7910	7921	7933	7944	7955	7967
380	57978	57990	58001	58013	58024	58035	58047	58058	58070	58081
1	8092	8104	8115	8127	8138	8149	8161	8172	8184	8195
2	8206	8218	8229	8240	8252	8263	8274	8286	8297	8309
3	8320	8331	8343	8354	8365	8377	8388	8399	8410	8422
4	8433	8444	8456	8467	8478	8490	8501	8512	8524	8535
5	8546	8557	8569	8580	8591	8602	8614	8625	8636	8647
6	8659	8670	8681	8692	8704	8715	8726	8737	8749	8760
7	8771	8782	8794	8805	8816	8827	8838	8850	8861	8872
8	8883	8894	8906	8917	8928	8939	8950	8961	8973	8984
9	8995	9006	9017	9028	9040	9051	9062	9073	9084	9095
390	59106	59118	59129	59140	59151	59162	59173	59184	59195	59207
1	9218	9229	9240	9251	9262	9273	9284	9295	9306	9318
2	9329	9340	9351	9362	9373	9384	9395	9406	9417	9428
3	9439	9450	9461	9472	9483	9494	9506	9517	9528	9539
4	9550	9561	9572	9583	9594	9605	9616	9627	9638	9649
5	9660	9671	9682	9693	9704	9715	9726	9737	9748	9759
6	9770	9780	9791	9802	9813	9824	9835	9846	9857	9868
7	9879	9890	9901	9912	9923	9934	9945	9956	9966	9977
8	9988	9999	60010	60021	60032	60043	60054	60065	60076	60086
9	60097	60108	0119	0130	0141	0152	0163	0173	0184	0195
400	60206	60217	60228	60239	60249	60260	60271	60282	60293	60304

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
400	60206	60217	60228	60239	60249	60260	60271	60282	60293	60304
1	0314	0325	0336	0347	0358	0369	0379	0390	0401	0412
2	0423	0433	0444	0455	0466	0477	0487	0498	0509	0520
3	0531	0541	0552	0563	0574	0584	0595	0606	0617	0627
4	0638	0649	0660	0670	0681	0692	0703	0713	0724	0735
5	0746	0756	0767	0778	0788	0799	0810	0821	0831	0842
6	0853	0863	0874	0885	0895	0906	0917	0927	0938	0949
7	0959	0970	0981	0991	1002	1013	1023	1034	1045	1055
8	1066	1077	1087	1098	1109	1119	1130	1140	1151	1162
9	1172	1183	1194	1204	1215	1225	1236	1247	1257	1268
410	61278	61289	61300	61310	61321	61331	61342	61352	61363	61374
1	1384	1395	1405	1416	1426	1437	1448	1458	1469	1479
2	1490	1500	1511	1521	1532	1542	1553	1563	1574	1584
3	1595	1606	1616	1627	1637	1648	1658	1669	1679	1690
4	1700	1711	1721	1731	1742	1752	1763	1773	1784	1794
5	1805	1815	1826	1836	1847	1857	1868	1878	1888	1899
6	1909	1920	1930	1941	1951	1962	1972	1982	1993	2003
7	2014	2024	2034	2045	2055	2066	2076	2086	2097	2107
8	2118	2128	2138	2149	2159	2170	2180	2190	2201	2211
9	2221	2232	2242	2252	2263	2273	2284	2294	2304	2315
420	62325	62335	62346	62356	62366	62377	62387	62397	62408	62418
1	2428	2439	2449	2459	2469	2480	2490	2500	2511	2521
2	2531	2542	2552	2562	2572	2583	2593	2603	2613	2624
3	2634	2644	2655	2665	2675	2685	2696	2706	2716	2726
4	2737	2747	2757	2767	2778	2788	2798	2808	2818	2829
5	2839	2849	2859	2870	2880	2890	2900	2910	2921	2931
6	2941	2951	2961	2972	2982	2992	3002	3012	3022	3033
7	3043	3053	3063	3073	3083	3094	3104	3114	3124	3134
8	3144	3155	3165	3175	3185	3195	3205	3215	3225	3236
9	3246	3256	3266	3276	3286	3296	3306	3317	3327	3337
430	63347	63357	63367	63377	63387	63397	63407	63417	63428	63438
1	3448	3458	3468	3478	3488	3498	3508	3518	3528	3538
2	3548	3558	3568	3579	3589	3599	3609	3619	3629	3639
3	3640	3650	3660	3679	3689	3699	3709	3719	3729	3739
4	3749	3759	3769	3779	3789	3799	3809	3819	3829	3839
5	3849	3859	3869	3879	3889	3899	3909	3919	3929	3939
6	3949	3959	3969	3979	3988	3998	4008	4018	4028	4038
7	4048	4058	4068	4078	4088	4098	4108	4118	4128	4137
8	4147	4157	4167	4177	4187	4197	4207	4217	4227	4237
9	4246	4256	4266	4276	4286	4296	4306	4316	4326	4335
440	64345	64355	64365	64375	64385	64395	64404	64414	64424	64434
1	4444	4454	4464	4473	4483	4493	4503	4513	4523	4532
2	4542	4552	4562	4572	4582	4591	4601	4611	4621	4631
3	4640	4650	4660	4670	4680	4689	4699	4709	4719	4729
4	4738	4748	4758	4768	4777	4787	4797	4807	4816	4826
5	4836	4846	4856	4865	4875	4885	4895	4904	4914	4924
6	4933	4943	4953	4963	4972	4982	4992	5002	5011	5021
7	5031	5040	5050	5060	5070	5079	5089	5099	5108	5118
8	5128	5137	5147	5157	5167	5176	5186	5196	5205	5215
9	5225	5234	5244	5254	5263	5273	5283	5292	5302	5312
450	65321	65331	65341	65350	65360	65369	65379	65389	65398	65408

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
450	65321	65331	65341	65350	65360	65369	65379	65389	65398	65408
1	5418	5427	5437	5447	5456	5466	5475	5485	5495	5504
2	5514	5523	5533	5543	5552	5562	5571	5581	5591	5600
3	5610	5619	5629	5639	5648	5658	5667	5677	5686	5696
4	5706	5715	5725	5734	5744	5753	5763	5772	5782	5792
5	5801	5811	5820	5830	5839	5849	5858	5868	5877	5887
6	5896	5906	5916	5925	5935	5944	5954	5963	5973	5982
7	5992	6001	6011	6020	6030	6039	6049	6058	6068	6077
8	6087	6096	6106	6115	6124	6134	6143	6153	6162	6172
9	6181	6191	6200	6210	6219	6229	6238	6247	6257	6266
460	66276	66285	66295	66304	66314	66323	66332	66342	66351	66361
1	6370	6380	6389	6398	6408	6417	6427	6436	6445	6455
2	6464	6474	6483	6492	6502	6511	6521	6530	6539	6549
3	6558	6567	6577	6586	6596	6605	6614	6624	6633	6642
4	6652	6661	6671	6680	6689	6699	6708	6717	6727	6736
5	6745	6755	6764	6773	6783	6792	6801	6811	6820	6829
6	6839	6848	6857	6867	6876	6885	6894	6904	6913	6922
7	6932	6941	6950	6960	6969	6978	6987	6997	7006	7015
8	7025	7034	7043	7052	7062	7071	7080	7089	7099	7108
9	7117	7127	7136	7145	7154	7164	7173	7182	7191	7201
470	67210	67219	67228	67237	67247	67256	67265	67274	67284	67293
1	7302	7311	7321	7330	7339	7348	7357	7367	7376	7385
2	7394	7403	7413	7422	7431	7440	7449	7459	7468	7477
3	7486	7495	7504	7514	7523	7532	7541	7550	7560	7569
4	7578	7587	7596	7605	7614	7624	7633	7642	7651	7660
5	7669	7679	7688	7697	7706	7715	7724	7733	7742	7752
6	7761	7770	7779	7788	7797	7806	7815	7825	7834	7843
7	7852	7861	7870	7879	7888	7897	7906	7916	7925	7934
8	7943	7952	7961	7970	7979	7988	7997	8006	8015	8024
9	8034	8043	8052	8061	8070	8079	8088	8097	8106	8115
480	68124	68133	68142	68151	68160	68169	68178	68187	68196	68205
1	8215	8224	8233	8242	8251	8260	8269	8278	8287	8296
2	8305	8314	8323	8332	8341	8350	8359	8368	8377	8386
3	8395	8404	8413	8422	8431	8440	8449	8458	8467	8476
4	8485	8494	8502	8511	8520	8529	8538	8547	8556	8565
5	8574	8583	8592	8601	8610	8619	8628	8637	8646	8655
6	8664	8673	8681	8690	8699	8708	8717	8726	8735	8744
7	8753	8762	8771	8780	8789	8797	8806	8815	8824	8833
8	8842	8851	8860	8869	8878	8886	8895	8904	8913	8922
9	8931	8940	8949	8958	8966	8975	8984	8993	9002	9011
490	69020	69028	69037	69046	69055	69064	69073	69082	69090	69099
1	9108	9117	9126	9135	9144	9152	9161	9170	9179	9188
2	9197	9205	9214	9223	9232	9241	9249	9258	9267	9276
3	9285	9294	9302	9311	9320	9329	9338	9346	9355	9364
4	9373	9381	9390	9399	9408	9417	9425	9434	9443	9452
5	9461	9469	9478	9487	9496	9504	9513	9522	9531	9539
6	9548	9557	9566	9574	9583	9592	9601	9609	9618	9627
7	9636	9644	9653	9662	9671	9679	9688	9697	9705	9714
8	9723	9732	9740	9749	9758	9767	9775	9784	9793	9801
9	9810	9819	9827	9836	9845	9854	9862	9871	9880	9888
500	69897	69906	69914	69923	69932	69940	69949	69958	69966	69975

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
500	69897	69906	69914	69923	69932	69940	69949	69958	69966	69975
1	9984	9992	70001	70010	70018	70027	70036	70044	70053	70062
2	70070	70079	0088	0096	0105	0114	0122	0131	0140	0148
3	0157	0165	0174	0183	0191	0200	0209	0217	0226	0234
4	0243	0252	0260	0269	0278	0286	0295	0303	0312	0321
5	0329	0338	0346	0355	0364	0372	0381	0389	0398	0406
6	0415	0424	0432	0441	0449	0458	0467	0475	0484	0492
7	0501	0509	0518	0526	0535	0544	0552	0561	0569	0578
8	0586	0595	0603	0612	0621	0629	0638	0646	0655	0663
9	0672	0680	0689	0697	0706	0714	0723	0731	0740	0749
510	70757	70766	70774	70783	70791	70800	70808	70817	70825	70834
1	0842	0851	0859	0868	0876	0885	0893	0902	0910	0919
2	0927	0935	0944	0952	0961	0969	0978	0986	0995	1003
3	1012	1020	1029	1037	1046	1054	1063	1071	1079	1088
4	1096	1105	1113	1122	1130	1139	1147	1155	1164	1172
5	1181	1189	1198	1206	1214	1223	1231	1240	1248	1257
6	1265	1273	1282	1290	1299	1307	1315	1324	1332	1341
7	1349	1357	1366	1374	1383	1391	1399	1408	1416	1425
8	1433	1441	1450	1458	1466	1475	1483	1492	1500	1508
9	1517	1525	1533	1542	1550	1559	1567	1575	1584	1592
520	71600	71609	71617	71625	71634	71642	71650	71659	71667	71675
1	1684	1692	1700	1709	1717	1725	1734	1742	1750	1759
2	1767	1775	1784	1792	1800	1809	1817	1825	1834	1842
3	1850	1858	1867	1875	1883	1892	1900	1908	1917	1925
4	1933	1941	1950	1958	1966	1975	1983	1991	1999	2008
5	2016	2024	2032	2041	2049	2057	2066	2074	2082	2090
6	2099	2107	2115	2123	2132	2140	2148	2156	2165	2173
7	2181	2189	2198	2206	2214	2222	2230	2239	2247	2255
8	2263	2272	2280	2288	2296	2304	2313	2321	2329	2337
9	2346	2354	2362	2370	2378	2387	2395	2403	2411	2419
530	72428	72436	72444	72452	72460	72469	72477	72485	72493	72501
1	2509	2518	2526	2534	2542	2550	2558	2567	2575	2583
2	2591	2599	2607	2616	2624	2632	2640	2648	2656	2665
3	2673	2681	2689	2697	2705	2713	2722	2730	2738	2746
4	2754	2762	2770	2779	2787	2795	2803	2811	2819	2827
5	2835	2843	2852	2860	2868	2876	2884	2892	2900	2908
6	2916	2925	2933	2941	2949	2957	2965	2973	2981	2989
7	2997	3006	3014	3022	3030	3038	3046	3054	3062	3070
8	3078	3086	3094	3102	3111	3119	3127	3135	3143	3151
9	3159	3167	3175	3183	3191	3199	3207	3215	3223	3231
540	73239	73247	73255	73263	73272	73280	73288	73296	73304	73312
1	3320	3328	3336	3344	3352	3360	3368	3376	3384	3392
2	3400	3408	3416	3424	3432	3440	3448	3456	3464	3472
3	3480	3488	3496	3504	3512	3520	3528	3536	3544	3552
4	3560	3568	3576	3584	3592	3600	3608	3616	3624	3632
5	3640	3648	3656	3664	3672	3679	3687	3695	3703	3711
6	3719	3727	3735	3743	3751	3759	3767	3775	3783	3791
7	3799	3807	3815	3823	3830	3838	3846	3854	3862	3870
8	3878	3886	3894	3902	3910	3918	3926	3933	3941	3949
9	3957	3965	3973	3981	3989	3997	4005	4013	4020	4028
550	74036	74044	74052	74060	74068	74076	74084	74092	74099	74107

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
550	74036	74044	74052	74060	74068	74076	74084	74092	74099	74107
1	4115	4123	4131	4139	4147	4155	4162	4170	4178	4186
2	4194	4202	4210	4218	4225	4233	4241	4249	4257	4265
3	4273	4280	4288	4296	4304	4312	4320	4327	4335	4343
4	4351	4359	4367	4374	4382	4390	4398	4406	4414	4421
5	4429	4437	4445	4453	4461	4468	4476	4484	4492	4500
6	4507	4515	4523	4531	4539	4547	4554	4562	4570	4578
7	4586	4593	4601	4609	4617	4624	4632	4640	4648	4656
8	4663	4671	4679	4687	4695	4702	4710	4718	4726	4733
9	4741	4749	4757	4764	4772	4780	4788	4796	4803	4811
560	74819	74827	74834	74842	74850	74858	74865	74873	74881	74889
1	4896	4904	4912	4920	4927	4935	4943	4950	4958	4966
2	4974	4981	4989	4997	5005	5012	5020	5028	5035	5043
3	5051	5059	5066	5074	5082	5089	5097	5105	5113	5120
4	5128	5136	5143	5151	5159	5166	5174	5182	5189	5197
5	5205	5213	5220	5228	5236	5243	5251	5259	5266	5274
6	5282	5289	5297	5305	5312	5320	5328	5335	5343	5351
7	5358	5366	5374	5381	5389	5397	5404	5412	5420	5427
8	5435	5442	5450	5458	5465	5473	5481	5488	5496	5504
9	5511	5519	5526	5534	5542	5549	5557	5565	5572	5580
570	75587	75595	75603	75610	75618	75626	75633	75641	75648	75656
1	5664	5671	5679	5686	5694	5702	5709	5717	5724	5732
2	5740	5747	5755	5762	5770	5778	5785	5793	5800	5808
3	5815	5823	5831	5838	5846	5853	5861	5868	5876	5884
4	5891	5899	5906	5914	5921	5929	5937	5944	5952	5959
5	5967	5974	5982	5989	5997	6005	6012	6020	6027	6035
6	6042	6050	6057	6065	6072	6080	6087	6095	6103	6110
7	6118	6125	6133	6140	6148	6155	6163	6170	6178	6185
8	6193	6200	6208	6215	6223	6230	6238	6245	6253	6260
9	6268	6275	6283	6290	6298	6305	6313	6320	6328	6335
580	76343	76350	76358	76365	76373	76380	76388	76395	76403	76410
1	6418	6425	6433	6440	6448	6455	6462	6470	6477	6485
2	6492	6500	6507	6515	6522	6530	6537	6545	6552	6559
3	6567	6574	6582	6589	6597	6604	6612	6619	6626	6634
4	6641	6649	6656	6664	6671	6678	6686	6693	6701	6708
5	6716	6723	6730	6738	6745	6753	6760	6768	6775	6782
6	6790	6797	6805	6812	6819	6827	6834	6842	6849	6856
7	6864	6871	6879	6886	6893	6901	6908	6916	6923	6930
8	6938	6945	6953	6960	6967	6975	6982	6989	6997	7004
9	7012	7019	7026	7034	7041	7048	7056	7063	7070	7078
590	77085	77093	77100	77107	77115	77122	77129	77137	77144	77151
1	7159	7166	7173	7181	7188	7195	7203	7210	7217	7225
2	7232	7240	7247	7254	7262	7269	7276	7283	7291	7298
3	7305	7313	7320	7327	7335	7342	7349	7357	7364	7371
4	7379	7386	7393	7401	7408	7415	7422	7430	7437	7444
5	7452	7459	7466	7474	7481	7488	7495	7503	7510	7517
6	7525	7532	7539	7546	7554	7561	7568	7576	7583	7590
7	7597	7605	7612	7619	7627	7634	7641	7648	7656	7663
8	7670	7677	7685	7692	7699	7706	7714	7721	7728	7735
9	7743	7750	7757	7764	7772	7779	7786	7793	7801	7808
600	77815	77822	77830	77837	77844	77851	77859	77866	77873	77880

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
600	77815	77822	77830	77837	77844	77851	77859	77866	77873	77880
1	7887	7895	7902	7909	7916	7924	7931	7938	7945	7952
2	7960	7967	7974	7981	7988	7996	8003	8010	8017	8025
3	8032	8039	8046	8053	8061	8068	8075	8082	8089	8097
4	8104	8111	8118	8125	8132	8140	8147	8154	8161	8168
5	8176	8183	8190	8197	8204	8211	8219	8226	8233	8240
6	8247	8254	8262	8269	8276	8283	8290	8297	8305	8312
7	8319	8326	8333	8340	8347	8355	8362	8369	8376	8383
8	8390	8398	8405	8412	8419	8426	8433	8440	8447	8455
9	8462	8469	8476	8483	8490	8497	8504	8512	8519	8526
610	78533	78540	78547	78554	78561	78569	78576	78583	78590	78597
1	8604	8611	8618	8625	8633	8640	8647	8654	8661	8668
2	8675	8682	8689	8696	8704	8711	8718	8725	8732	8739
3	8746	8753	8760	8767	8774	8781	8789	8796	8803	8810
4	8817	8824	8831	8838	8845	8852	8859	8866	8873	8880
5	8888	8895	8902	8909	8916	8923	8930	8937	8944	8951
6	8958	8965	8972	8979	8986	8993	9000	9007	9014	9021
7	9029	9036	9043	9050	9057	9064	9071	9078	9085	9092
8	9099	9106	9113	9120	9127	9134	9141	9148	9155	9162
9	9169	9176	9183	9190	9197	9204	9211	9218	9225	9232
620	79239	79246	79253	79260	79267	79274	79281	79288	79295	79302
1	9309	9316	9323	9330	9337	9344	9351	9358	9365	9372
2	9379	9386	9393	9400	9407	9414	9421	9428	9435	9442
3	9449	9456	9463	9470	9477	9484	9491	9498	9505	9511
4	9518	9525	9532	9539	9546	9553	9560	9567	9574	9581
5	9588	9595	9602	9609	9616	9623	9630	9637	9644	9650
6	9657	9664	9671	9678	9685	9692	9699	9706	9713	9720
7	9727	9734	9741	9748	9754	9761	9768	9775	9782	9789
8	9796	9803	9810	9817	9824	9831	9837	9844	9851	9858
9	9865	9872	9879	9886	9893	9900	9906	9913	9920	9927
630	79934	79941	79948	79955	79962	79969	79975	79982	79989	79996
1	80003	80010	80017	80024	80030	80037	80044	80051	80058	80065
2	0072	0079	0085	0092	0099	0106	0113	0120	0127	0134
3	0140	0147	0154	0161	0168	0175	0182	0188	0195	0202
4	0209	0216	0223	0229	0236	0243	0250	0257	0264	0271
5	0277	0284	0291	0298	0305	0312	0318	0325	0332	0339
6	0346	0353	0359	0366	0373	0380	0387	0393	0400	0407
7	0414	0421	0428	0434	0441	0448	0455	0462	0468	0475
8	0482	0489	0496	0502	0509	0516	0523	0530	0536	0543
9	0550	0557	0564	0570	0577	0584	0591	0598	0604	0611
640	80618	80625	80632	80638	80645	80652	80659	80665	80672	80679
1	0686	0693	0699	0706	0713	0720	0726	0733	0740	0747
2	0754	0760	0767	0774	0781	0787	0794	0801	0808	0814
3	0821	0828	0835	0841	0848	0855	0862	0868	0875	0882
4	0889	0895	0902	0909	0916	0922	0929	0936	0943	0949
5	0956	0963	0969	0976	0983	0990	0996	1003	1010	1017
6	1023	1030	1037	1043	1050	1057	1064	1070	1077	1084
7	1090	1097	1104	1111	1117	1124	1131	1137	1144	1151
8	1158	1164	1171	1178	1184	1191	1198	1204	1211	1218
9	1224	1231	1238	1245	1251	1258	1265	1271	1278	1285
650	81291	81298	81305	81311	81318	81325	81331	81338	81345	81351

TABLE 1A.—LOGARITHMS OF NUMBERS.

0	1	2	3	4	5	6	7	8	9
81291	81298	81305	81311	81318	81325	81331	81338	81345	81351
1358	1365	1371	1378	1385	1391	1398	1405	1411	1418
1425	1431	1438	1445	1451	1458	1465	1471	1478	1485
1491	1498	1505	1511	1518	1525	1531	1538	1544	1551
1558	1564	1571	1578	1584	1591	1598	1604	1611	1617
1624	1631	1637	1644	1651	1657	1664	1671	1677	1684
1690	1697	1704	1710	1717	1723	1730	1737	1743	1750
1757	1763	1770	1776	1783	1790	1796	1803	1809	1816
1823	1829	1836	1842	1849	1856	1862	1869	1875	1882
1889	1895	1902	1908	1915	1921	1928	1935	1941	1948
81954	81961	81968	81974	81981	81987	81994	82000	82007	82014
2020	2027	2033	2040	2046	2053	2060	2066	2073	2079
2086	2092	2099	2105	2112	2119	2125	2132	2138	2145
2151	2158	2164	2171	2178	2184	2191	2197	2204	2210
2217	2223	2230	2236	2243	2249	2256	2263	2269	2276
2282	2289	2295	2302	2308	2315	2321	2328	2334	2341
2347	2354	2360	2367	2373	2380	2387	2393	2400	2406
2413	2419	2426	2432	2439	2445	2452	2458	2465	2471
2478	2484	2491	2497	2504	2510	2517	2523	2530	2536
2543	2549	2556	2562	2569	2575	2582	2588	2595	2601
82607	82614	82620	82627	82633	82640	82646	82653	82659	82666
2672	2679	2685	2692	2698	2705	2711	2718	2724	2730
2737	2743	2750	2756	2763	2769	2776	2782	2789	2795
2802	2808	2814	2821	2827	2834	2840	2847	2853	2860
2866	2872	2879	2885	2892	2898	2905	2911	2918	2924
2930	2937	2943	2950	2956	2963	2969	2975	2982	2988
2995	3001	3008	3014	3020	3027	3033	3040	3046	3052
3059	3065	3072	3078	3085	3091	3097	3104	3110	3117
3123	3129	3136	3142	3149	3155	3161	3168	3174	3181
3187	3193	3200	3206	3213	3219	3225	3232	3238	3245
83251	83257	83264	83270	83276	83283	83289	83296	83302	83308
3315	3321	3327	3334	3340	3347	3353	3359	3366	3372
3378	3385	3391	3398	3404	3410	3417	3423	3429	3436
3442	3448	3455	3461	3467	3474	3480	3487	3493	3499
3506	3512	3518	3525	3531	3537	3544	3550	3556	3563
3569	3575	3582	3588	3594	3601	3607	3613	3620	3626
3632	3639	3645	3651	3658	3664	3670	3677	3683	3689
3696	3702	3708	3715	3721	3727	3734	3740	3746	3753
3759	3765	3771	3778	3784	3790	3797	3803	3809	3816
3822	3828	3835	3841	3847	3853	3860	3866	3872	3879
83885	83891	83897	83904	83910	83916	83923	83929	83935	83942
3948	3954	3960	3967	3973	3979	3985	3992	3998	4004
4011	4017	4023	4029	4036	4042	4048	4055	4061	4067
4073	4080	4086	4092	4098	4105	4111	4117	4123	4130
4136	4142	4148	4155	4161	4167	4173	4180	4186	4192
4198	4205	4211	4217	4223	4230	4236	4242	4248	4255
4261	4267	4273	4280	4286	4292	4298	4305	4311	4317
4323	4330	4336	4342	4348	4354	4361	4367	4373	4379
4386	4392	4398	4404	4410	4417	4423	4429	4435	4442
4448	4454	4460	4466	4473	4479	4485	4491	4497	4504
4510	84516	84522	84528	84535	84541	84547	84553	84559	84566

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
700	84510	84516	84522	84528	84535	84541	84547	84553	84559	84566
1	4572	4578	4584	4590	4597	4603	4609	4615	4621	4628
2	4634	4640	4646	4652	4658	4665	4671	4677	4683	4689
3	4696	4702	4708	4714	4720	4726	4733	4739	4745	4751
4	4757	4763	4770	4776	4782	4788	4794	4800	4807	4813
5	4819	4825	4831	4837	4844	4850	4856	4862	4868	4874
6	4880	4887	4893	4899	4905	4911	4917	4924	4930	4936
7	4942	4948	4954	4960	4967	4973	4979	4985	4991	4997
8	5003	5009	5016	5022	5028	5034	5040	5046	5052	5058
9	5065	5071	5077	5083	5089	5095	5101	5107	5114	5120
710	85126	85132	85138	85144	85150	85156	85163	85169	85175	85181
1	5187	5193	5199	5205	5211	5217	5224	5230	5236	5242
2	5248	5254	5260	5266	5272	5278	5285	5291	5297	5303
3	5309	5315	5321	5327	5333	5339	5345	5352	5358	5364
4	5370	5376	5382	5388	5394	5400	5406	5412	5418	5425
5	5431	5437	5443	5449	5455	5461	5467	5473	5479	5485
6	5491	5497	5503	5509	5516	5522	5528	5534	5540	5546
7	5552	5558	5564	5570	5576	5582	5588	5594	5600	5606
8	5612	5618	5625	5631	5637	5643	5649	5655	5661	5667
9	5673	5679	5685	5691	5697	5703	5709	5715	5721	5727
720	85733	85739	85745	85751	85757	85763	85769	85775	85781	85788
1	5794	5800	5806	5812	5818	5824	5830	5836	5842	5848
2	5854	5860	5866	5872	5878	5884	5890	5896	5902	5908
3	5914	5920	5926	5932	5938	5944	5950	5956	5962	5968
4	5974	5980	5986	5992	5998	6004	6010	6016	6022	6028
5	6034	6040	6046	6052	6058	6064	6070	6076	6082	6088
6	6094	6100	6106	6112	6118	6124	6130	6136	6141	6147
7	6153	6159	6165	6171	6177	6183	6189	6195	6201	6207
8	6213	6219	6225	6231	6237	6243	6249	6255	6261	6267
9	6273	6279	6285	6291	6297	6303	6308	6314	6320	6326
730	86332	86338	86344	86350	86356	86362	86368	86374	86380	86386
1	6392	6398	6404	6410	6415	6421	6427	6433	6439	6445
2	6451	6457	6463	6469	6475	6481	6487	6493	6499	6504
3	6510	6516	6522	6528	6534	6540	6546	6552	6558	6564
4	6570	6576	6581	6587	6593	6599	6605	6611	6617	6623
5	6629	6635	6641	6646	6652	6658	6664	6670	6676	6682
6	6688	6694	6700	6705	6711	6717	6723	6729	6735	6741
7	6747	6753	6759	6764	6770	6776	6782	6788	6794	6800
8	6806	6812	6817	6823	6829	6835	6841	6847	6853	6859
9	6864	6870	6876	6882	6888	6894	6900	6906	6911	6917
740	86923	86929	86935	86941	86947	86953	86958	86964	86970	86976
1	6982	6988	6994	6999	7005	7011	7017	7023	7029	7035
2	7040	7046	7052	7058	7064	7070	7075	7081	7087	7093
3	7099	7105	7111	7116	7122	7128	7134	7140	7146	7151
4	7157	7163	7169	7175	7181	7186	7192	7198	7204	7210
5	7216	7221	7227	7233	7239	7245	7251	7256	7262	7268
6	7274	7280	7286	7291	7297	7303	7309	7315	7320	7326
7	7332	7338	7344	7349	7355	7361	7367	7373	7379	7384
8	7390	7396	7402	7408	7413	7419	7425	7431	7437	7442
9	7448	7454	7460	7466	7471	7477	7483	7489	7495	7500
750	87506	87512	87518	87523	87529	87535	87541	87547	87552	87558

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
750	87506	87512	87518	87523	87529	87535	87541	87547	87552	87558
1	7564	7570	7576	7581	7587	7593	7599	7604	7610	7616
2	7622	7628	7633	7639	7645	7651	7656	7662	7668	7674
3	7679	7685	7691	7697	7703	7708	7714	7720	7726	7731
4	7737	7743	7749	7754	7760	7766	7772	7777	7783	7789
5	7795	7800	7806	7812	7818	7823	7829	7835	7841	7846
6	7852	7858	7864	7869	7875	7881	7887	7892	7898	7904
7	7910	7915	7921	7927	7933	7938	7944	7950	7955	7961
8	7967	7973	7978	7984	7990	7996	8001	8007	8013	8018
9	8024	8030	8036	8041	8047	8053	8058	8064	8070	8076
760	88081	88087	88093	88098	88104	88110	88116	88121	88127	88133
1	8138	8144	8150	8156	8161	8167	8173	8178	8184	8190
2	8195	8201	8207	8213	8218	8224	8230	8235	8241	8247
3	8252	8258	8264	8270	8275	8281	8287	8292	8298	8304
4	8309	8315	8321	8326	8332	8338	8343	8349	8355	8360
5	8366	8372	8377	8383	8389	8395	8400	8406	8412	8417
6	8423	8429	8434	8440	8446	8451	8457	8463	8468	8474
7	8480	8485	8491	8497	8502	8508	8513	8519	8525	8530
8	8536	8542	8547	8553	8559	8564	8570	8576	8581	8587
9	8593	8598	8604	8610	8615	8621	8627	8632	8638	8643
770	88649	88655	88660	88666	88672	88677	88683	88689	88694	88700
1	8705	8711	8717	8722	8728	8734	8739	8745	8750	8756
2	8762	8767	8773	8779	8784	8790	8795	8801	8807	8812
3	8818	8824	8829	8835	8840	8846	8852	8857	8863	8868
4	8874	8880	8885	8891	8897	8902	8908	8913	8919	8925
5	8930	8936	8941	8947	8953	8958	8964	8969	8975	8981
6	8986	8992	8997	9003	9009	9014	9020	9025	9031	9037
7	9042	9048	9053	9059	9064	9070	9076	9081	9087	9092
8	9098	9104	9109	9115	9120	9126	9131	9137	9143	9148
9	9154	9159	9165	9170	9176	9182	9187	9193	9198	9204
780	89209	89215	89221	89226	89232	89237	89243	89248	89254	89260
1	9265	9271	9276	9282	9287	9293	9298	9304	9310	9315
2	9321	9326	9332	9337	9343	9348	9354	9360	9365	9371
3	9376	9382	9387	9393	9398	9404	9409	9415	9421	9426
4	9432	9437	9443	9448	9454	9459	9465	9470	9476	9481
5	9487	9492	9498	9504	9509	9515	9520	9526	9531	9537
6	9542	9548	9553	9559	9564	9570	9575	9581	9586	9592
7	9597	9603	9609	9614	9620	9625	9631	9636	9642	9647
8	9653	9658	9664	9669	9675	9680	9686	9691	9697	9702
9	9708	9713	9719	9724	9730	9735	9741	9746	9752	9757
790	89763	89768	89774	89779	89785	89790	89796	89801	89807	89812
1	9818	9823	9829	9834	9840	9845	9851	9856	9862	9867
2	9873	9878	9883	9889	9894	9900	9905	9911	9916	9922
3	9927	9933	9938	9944	9949	9955	9960	9966	9971	9977
4	9982	9988	9993	9998	9999	9999	9999	9999	9999	9999
5	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999
6	0091	0097	0102	0108	0113	0119	0124	0129	0135	0140
7	0146	0151	0157	0162	0168	0173	0179	0184	0189	0195
8	0200	0206	0211	0217	0222	0227	0233	0238	0244	0249
9	0255	0260	0266	0271	0276	0282	0287	0293	0298	0304
800	90309	90314	90320	90325	90331	90336	90342	90347	90352	90358

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
800	90309	90314	90320	90325	90331	90336	90342	90347	90352	90358
1	0363	0369	0374	0380	0385	0390	0396	0401	0407	0412
2	0417	0423	0428	0434	0439	0445	0450	0455	0461	0466
3	0472	0477	0482	0488	0493	0499	0504	0509	0515	0520
4	0526	0531	0536	0542	0547	0553	0558	0563	0569	0574
5	0580	0585	0590	0596	0601	0607	0612	0617	0623	0628
6	0634	0639	0644	0650	0655	0660	0666	0671	0677	0682
7	0687	0693	0698	0703	0709	0714	0720	0725	0730	0736
8	0741	0747	0752	0757	0763	0768	0773	0779	0784	0789
9	0795	0800	0806	0811	0816	0822	0827	0832	0838	0843
810	90849	90854	90859	90865	90870	90875	90881	90886	90891	90897
1	0902	0907	0913	0918	0924	0929	0934	0940	0945	0950
2	0956	0961	0966	0972	0977	0982	0988	0993	0998	1004
3	1009	1014	1020	1025	1030	1036	1041	1046	1052	1057
4	1062	1068	1073	1078	1084	1089	1094	1100	1105	1110
5	1116	1121	1126	1132	1137	1142	1148	1153	1158	1164
6	1169	1174	1180	1185	1190	1196	1201	1206	1212	1217
7	1222	1228	1233	1238	1243	1249	1254	1259	1265	1270
8	1275	1281	1286	1291	1297	1302	1307	1312	1318	1323
9	1328	1334	1339	1344	1350	1355	1360	1365	1371	1376
820	91381	91387	91392	91397	91403	91408	91413	91418	91424	91429
1	1434	1440	1445	1450	1455	1461	1466	1471	1477	1482
2	1487	1492	1498	1503	1508	1514	1519	1524	1529	1535
3	1540	1545	1551	1556	1561	1566	1572	1577	1582	1587
4	1593	1598	1603	1609	1614	1619	1624	1630	1635	1640
5	1645	1651	1656	1661	1666	1672	1677	1682	1687	1693
6	1698	1703	1709	1714	1719	1724	1730	1735	1740	1745
7	1751	1756	1761	1766	1772	1777	1782	1787	1793	1798
8	1803	1808	1814	1819	1824	1829	1834	1840	1845	1850
9	1855	1861	1866	1871	1876	1882	1887	1892	1897	1903
830	91908	91913	91918	91924	91929	91934	91939	91944	91950	91955
1	1960	1965	1971	1976	1981	1986	1991	1997	2002	2007
2	2012	2018	2023	2028	2033	2038	2044	2049	2054	2059
3	2065	2070	2075	2080	2085	2091	2096	2101	2106	2111
4	2117	2122	2127	2132	2137	2143	2148	2153	2158	2163
5	2169	2174	2179	2184	2189	2195	2200	2205	2210	2215
6	2221	2226	2231	2236	2241	2247	2252	2257	2262	2267
7	2273	2278	2283	2288	2293	2298	2304	2309	2314	2319
8	2324	2330	2335	2340	2345	2350	2355	2361	2366	2371
9	2376	2381	2387	2392	2397	2402	2407	2412	2418	2423
840	92428	92433	92438	92443	92449	92454	92459	92464	92469	92474
1	2480	2485	2490	2495	2500	2505	2511	2516	2521	2526
2	2531	2536	2542	2547	2552	2557	2562	2567	2572	2578
3	2583	2588	2593	2598	2603	2609	2614	2619	2624	2629
4	2634	2639	2645	2650	2655	2660	2665	2670	2675	2681
5	2686	2691	2696	2701	2706	2711	2716	2722	2727	2732
6	2737	2742	2747	2752	2758	2763	2768	2773	2778	2783
7	2788	2793	2799	2804	2809	2814	2819	2824	2829	2834
8	2840	2845	2850	2855	2860	2865	2870	2875	2881	2886
9	2891	2896	2901	2906	2911	2916	2921	2927	2932	2937
850	92942	92947	92952	92957	92962	92967	92973	92978	92983	92988

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
850	92942	92947	92952	92957	92962	92967	92973	92978	92983	92988
1	2993	2998	3003	3008	3013	3018	3024	3029	3034	3039
2	3044	3049	3054	3059	3064	3069	3075	3080	3085	3090
3	3095	3100	3105	3110	3115	3120	3125	3131	3136	3141
4	3146	3151	3156	3161	3166	3171	3176	3181	3186	3192
5	3197	3202	3207	3212	3217	3222	3227	3232	3237	3242
6	3247	3252	3258	3263	3268	3273	3278	3283	3288	3293
7	3298	3303	3308	3313	3318	3323	3328	3334	3339	3344
8	3349	3354	3359	3364	3369	3374	3379	3384	3389	3394
9	3399	3404	3409	3414	3420	3425	3430	3435	3440	3445
860	93450	93455	93460	93465	93470	93475	93480	93485	93490	93495
1	3500	3505	3510	3515	3520	3526	3531	3536	3541	3546
2	3551	3556	3561	3566	3571	3576	3581	3586	3591	3596
3	3601	3606	3611	3616	3621	3626	3631	3636	3641	3646
4	3651	3656	3661	3666	3671	3676	3682	3687	3692	3697
5	3702	3707	3712	3717	3722	3727	3732	3737	3742	3747
6	3752	3757	3762	3767	3772	3777	3782	3787	3792	3797
7	3802	3807	3812	3817	3822	3827	3832	3837	3842	3847
8	3852	3857	3862	3867	3872	3877	3882	3887	3892	3897
9	3902	3907	3912	3917	3922	3927	3932	3937	3942	3947
870	93952	93957	93962	93967	93972	93977	93982	93987	93992	93997
1	4002	4007	4012	4017	4022	4027	4032	4037	4042	4047
2	4052	4057	4062	4067	4072	4077	4082	4086	4091	4096
3	4101	4106	4111	4116	4121	4126	4131	4136	4141	4146
4	4151	4156	4161	4166	4171	4176	4181	4186	4191	4196
5	4201	4206	4211	4216	4221	4226	4231	4236	4240	4245
6	4250	4255	4260	4265	4270	4275	4280	4285	4290	4295
7	4300	4305	4310	4315	4320	4325	4330	4335	4340	4345
8	4349	4354	4359	4364	4369	4374	4379	4384	4389	4394
9	4399	4404	4409	4414	4419	4424	4429	4433	4438	4443
880	94448	94453	94458	94463	94468	94473	94478	94483	94488	94493
1	4498	4503	4507	4512	4517	4522	4527	4532	4537	4542
2	4547	4552	4557	4562	4567	4571	4576	4581	4586	4591
3	4596	4601	4606	4611	4616	4621	4626	4630	4635	4640
4	4645	4650	4655	4660	4665	4670	4675	4680	4685	4689
5	4694	4699	4704	4709	4714	4719	4724	4729	4734	4738
6	4743	4748	4753	4758	4763	4768	4773	4778	4783	4787
7	4792	4797	4802	4807	4812	4817	4822	4827	4832	4836
8	4841	4846	4851	4856	4861	4866	4871	4876	4880	4885
9	4890	4895	4900	4905	4910	4915	4919	4924	4929	4934
890	94939	94944	94949	94954	94959	94963	94968	94973	94978	94983
1	4988	4993	4998	5002	5007	5012	5017	5022	5027	5032
2	5036	5041	5046	5051	5056	5061	5066	5071	5075	5080
3	5085	5090	5095	5100	5105	5109	5114	5119	5124	5129
4	5134	5139	5143	5148	5153	5158	5163	5168	5173	5177
5	5182	5187	5192	5197	5202	5207	5211	5216	5221	5226
6	5231	5236	5240	5245	5250	5255	5260	5265	5270	5274
7	5279	5284	5289	5294	5299	5303	5308	5313	5318	5323
8	5328	5332	5337	5342	5347	5352	5357	5361	5366	5371
9	5376	5381	5386	5390	5395	5400	5405	5410	5415	5419
900	95424	95429	95434	95439	95444	95448	95453	95458	95463	95468

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
900	95424	95429	95434	95439	95444	95448	95453	95458	95463	95468
1	5472	5477	5482	5487	5492	5497	5501	5506	5511	5516
2	5521	5525	5530	5535	5540	5545	5550	5554	5559	5564
3	5569	5574	5578	5583	5588	5593	5598	5602	5607	5612
4	5617	5622	5626	5631	5636	5641	5646	5650	5655	5660
5	5665	5670	5674	5679	5684	5689	5694	5698	5703	5708
6	5713	5718	5722	5727	5732	5737	5742	5746	5751	5756
7	5761	5766	5770	5775	5780	5785	5789	5794	5799	5804
8	5809	5813	5818	5823	5828	5832	5837	5842	5847	5852
9	5856	5861	5866	5871	5875	5880	5885	5890	5895	5899
910	95904	95909	95914	95918	95923	95928	95933	95938	95942	95947
1	5952	5957	5961	5966	5971	5976	5980	5985	5990	5995
2	5999	6004	6009	6014	6019	6023	6028	6033	6038	6042
3	6047	6052	6057	6061	6066	6071	6076	6080	6085	6090
4	6095	6099	6104	6109	6114	6118	6123	6128	6133	6137
5	6142	6147	6152	6156	6161	6166	6171	6175	6180	6185
6	6190	6194	6199	6204	6209	6213	6218	6223	6227	6232
7	6237	6242	6246	6251	6256	6261	6265	6270	6275	6280
8	6284	6289	6294	6298	6303	6308	6313	6317	6322	6327
9	6332	6336	6341	6346	6350	6355	6360	6365	6369	6374
920	96379	96384	96388	96393	96398	96402	96407	96412	96417	96421
1	6426	6431	6435	6440	6445	6450	6454	6459	6464	6468
2	6473	6478	6483	6487	6492	6497	6501	6506	6511	6515
3	6520	6525	6530	6534	6539	6544	6548	6553	6558	6562
4	6567	6572	6577	6581	6586	6591	6595	6600	6605	6609
5	6614	6619	6624	6628	6633	6638	6642	6647	6652	6656
6	6661	6666	6670	6675	6680	6685	6689	6694	6699	6703
7	6708	6713	6717	6722	6727	6731	6736	6741	6745	6750
8	6755	6759	6764	6769	6774	6778	6783	6788	6792	6797
9	6802	6806	6811	6816	6820	6825	6830	6834	6839	6844
930	96848	96853	96858	96862	96867	96872	96876	96881	96886	96890
1	6895	6900	6904	6909	6914	6918	6923	6928	6932	6937
2	6942	6946	6951	6956	6960	6965	6970	6974	6979	6984
3	6988	6993	6997	7002	7007	7011	7016	7021	7025	7030
4	7035	7039	7044	7049	7053	7058	7063	7067	7072	7077
5	7081	7086	7090	7095	7100	7104	7109	7114	7118	7123
6	7128	7132	7137	7142	7146	7151	7155	7160	7165	7169
7	7174	7179	7183	7188	7192	7197	7202	7206	7211	7216
8	7220	7225	7230	7234	7239	7243	7248	7253	7257	7262
9	7267	7271	7276	7280	7285	7290	7294	7299	7304	7308
940	97313	97317	97322	97327	97331	97336	97340	97345	97350	97354
1	7350	7364	7368	7373	7377	7382	7387	7391	7396	7400
2	7405	7410	7414	7419	7424	7428	7433	7437	7442	7447
3	7451	7456	7460	7465	7470	7474	7479	7483	7488	7493
4	7497	7502	7506	7511	7516	7520	7525	7529	7534	7539
5	7543	7548	7552	7557	7562	7566	7571	7575	7580	7585
6	7589	7594	7598	7603	7607	7612	7617	7621	7626	7630
7	7635	7640	7644	7649	7653	7658	7663	7667	7672	7676
8	7681	7685	7690	7695	7699	7704	7708	7713	7717	7722
9	7727	7731	7736	7740	7745	7749	7754	7759	7763	7768
950	97772	97777	97782	97786	97791	97795	97800	97804	97809	97813

TABLE IX. — LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
950	97772	97777	97782	97786	97791	97795	97800	97804	97809	97813
1	7818	7823	7827	7832	7836	7841	7845	7850	7855	7859
2	7864	7868	7873	7877	7882	7886	7891	7896	7900	7905
3	7909	7914	7918	7923	7928	7932	7937	7941	7946	7950
4	7955	7959	7964	7968	7973	7978	7982	7987	7991	7996
5	8000	8005	8009	8014	8019	8023	8028	8032	8037	8041
6	8046	8050	8055	8059	8064	8068	8073	8078	8082	8087
7	8091	8096	8100	8105	8109	8114	8118	8123	8127	8132
8	8137	8141	8146	8150	8155	8159	8164	8168	8173	8177
9	8182	8186	8191	8195	8200	8204	8209	8214	8218	8223
960	98227	98232	98236	98241	98245	98250	98254	98259	98263	98268
1	8272	8277	8281	8286	8290	8295	8299	8304	8308	8313
2	8318	8322	8327	8331	8336	8340	8345	8349	8354	8358
3	8363	8367	8372	8376	8381	8385	8390	8394	8399	8403
4	8408	8412	8417	8421	8426	8430	8435	8439	8444	8448
5	8453	8457	8462	8466	8471	8475	8480	8484	8489	8493
6	8498	8502	8507	8511	8516	8520	8525	8529	8534	8538
7	8543	8547	8552	8556	8561	8565	8570	8574	8579	8583
8	8588	8592	8597	8601	8605	8610	8614	8619	8623	8628
9	8632	8637	8641	8646	8650	8655	8659	8664	8668	8673
970	98677	98682	98686	98691	98695	98700	98704	98709	98713	98717
1	8722	8726	8731	8735	8740	8744	8749	8753	8758	8762
2	8767	8771	8776	8780	8784	8789	8793	8798	8802	8807
3	8811	8816	8820	8825	8829	8834	8838	8843	8847	8851
4	8856	8860	8865	8869	8874	8878	8883	8887	8892	8896
5	8900	8905	8909	8914	8918	8923	8927	8932	8936	8941
6	8945	8949	8954	8958	8963	8967	8972	8976	8981	8985
7	8989	8994	8998	9003	9007	9012	9016	9021	9025	9029
8	9034	9038	9043	9047	9052	9056	9061	9065	9069	9074
9	9078	9083	9087	9092	9096	9100	9105	9109	9114	9118
980	99123	99127	99131	99136	99140	99145	99149	99154	99158	99162
1	9167	9171	9176	9180	9185	9189	9193	9198	9202	9207
2	9211	9216	9220	9224	9229	9233	9238	9242	9247	9251
3	9255	9260	9264	9269	9273	9277	9282	9286	9291	9295
4	9300	9304	9308	9313	9317	9322	9326	9330	9335	9339
5	9344	9348	9352	9357	9361	9366	9370	9374	9379	9383
6	9388	9392	9396	9401	9405	9410	9414	9419	9423	9427
7	9432	9436	9441	9445	9449	9454	9458	9463	9467	9471
8	9476	9480	9484	9489	9493	9498	9502	9506	9511	9515
9	9520	9524	9528	9533	9537	9542	9546	9550	9555	9559
990	99564	99568	99572	99577	99581	99585	99590	99594	99599	99603
1	9607	9612	9616	9621	9625	9629	9634	9638	9642	9647
2	9651	9656	9660	9664	9669	9673	9677	9682	9686	9691
3	9695	9699	9704	9708	9712	9717	9721	9726	9730	9734
4	9739	9743	9747	9752	9756	9760	9765	9769	9774	9778
5	9782	9787	9791	9795	9800	9804	9808	9813	9817	9822
6	9826	9830	9835	9839	9843	9848	9852	9856	9861	9865
7	9870	9874	9878	9883	9887	9891	9896	9900	9904	9909
8	9913	9917	9922	9926	9930	9935	9939	9944	9948	9952
9	9957	9961	9965	9970	9974	9978	9983	9987	9991	9996
1000	00000	00004	00009	00013	00017	00022	00026	00030	00035	00039

TABLE X.—SINES AND COSINES.

	0°		1°		2°		3°		4°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	00000	One.	01745	99985	03490	99939	05234	99863	06976	99756	60
1	00029	One.	01774	99984	03519	99938	05263	99861	07005	99754	59
2	00058	One.	01803	99984	03548	99937	05292	99860	07034	99752	58
3	00087	One.	01832	99983	03577	99936	05321	99858	07063	99750	57
4	00116	One.	01862	99983	03606	99935	05350	99857	07092	99748	56
5	00145	One.	01891	99982	03635	99934	05379	99855	07121	99746	55
6	00175	One.	01920	99982	03664	99933	05408	99854	07150	99744	54
7	00204	One.	01949	99981	03693	99932	05437	99852	07179	99742	53
8	00233	One.	01978	99980	03722	99931	05466	99851	07208	99740	52
9	00262	One.	02007	99980	03752	99930	05495	99849	07237	99738	51
10	00291	One.	02036	99979	03781	99929	05524	99847	07266	99736	50
11	00320	99999	02065	99979	03810	99927	05553	99846	07295	99734	49
12	00349	99999	02094	99978	03839	99926	05582	99844	07324	99731	48
13	00378	99999	02123	99977	03868	99925	05611	99842	07353	99729	47
14	00407	99999	02152	99977	03897	99924	05640	99841	07382	99727	46
15	00436	99999	02181	99976	03926	99923	05669	99839	07411	99725	45
16	00465	99999	02211	99976	03955	99922	05698	99838	07440	99723	44
17	00495	99999	02240	99975	03984	99921	05727	99836	07469	99721	43
18	00524	99999	02269	99974	04013	99919	05756	99834	07498	99719	42
19	00553	99998	02298	99974	04042	99918	05785	99833	07527	99716	41
20	00582	99998	02327	99973	04071	99917	05814	99831	07556	99714	40
21	00611	99998	02356	99972	04100	99916	05844	99829	07585	99712	39
22	00640	99998	02385	99972	04129	99915	05873	99827	07614	99710	38
23	00669	99998	02414	99971	04159	99913	05902	99826	07643	99708	37
24	00698	99998	02443	99970	04188	99912	05931	99824	07672	99705	36
25	00727	99997	02472	99969	04217	99911	05960	99822	07701	99703	35
26	00756	99997	02501	99969	04246	99910	05989	99821	07730	99701	34
27	00785	99997	02530	99968	04275	99909	06018	99819	07759	99699	33
28	00814	99997	02560	99967	04304	99907	06047	99817	07788	99696	32
29	00844	99996	02589	99966	04333	99906	06076	99815	07817	99694	31
30	00873	99996	02618	99966	04362	99905	06105	99813	07846	99692	30
31	00902	99996	02647	99965	04391	99904	06134	99812	07875	99689	29
32	00931	99996	02676	99964	04420	99902	06163	99810	07904	99687	28
33	00960	99995	02705	99963	04449	99901	06192	99808	07933	99685	27
34	00989	99995	02734	99963	04478	99900	06221	99806	07962	99683	26
35	01018	99995	02763	99962	04507	99898	06250	99804	07991	99680	25
36	01047	99995	02792	99961	04536	99897	06279	99803	08020	99678	24
37	01076	99994	02821	99960	04565	99896	06308	99801	08049	99676	23
38	01105	99994	02850	99959	04594	99894	06337	99799	08078	99673	22
39	01134	99994	02879	99959	04623	99893	06366	99797	08107	99671	21
40	01164	99993	02908	99958	04653	99892	06395	99795	08136	99668	20
41	01193	99993	02936	99957	04682	99890	06424	99793	08165	99666	19
42	01222	99993	02967	99956	04711	99889	06453	99792	08194	99664	18
43	01251	99992	02996	99955	04740	99888	06482	99790	08223	99661	17
44	01280	99992	03025	99954	04769	99886	06511	99788	08252	99659	16
45	01309	99991	03054	99953	04798	99885	06540	99786	08281	99657	15
46	01338	99991	03083	99952	04827	99883	06569	99784	08310	99654	14
47	01367	99991	03112	99952	04856	99882	06598	99782	08339	99652	13
48	01396	99990	03141	99951	04885	99881	06627	99780	08368	99649	12
49	01425	99990	03170	99950	04914	99879	06656	99778	08397	99647	11
50	01454	99989	03199	99949	04943	99878	06685	99776	08426	99644	10
51	01483	99989	03228	99948	04972	99876	06714	99774	08455	99642	9
52	01513	99989	03257	99947	05001	99875	06743	99772	08484	99639	8
53	01542	99988	03286	99946	05030	99873	06773	99770	08513	99637	7
54	01571	99988	03316	99945	05059	99872	06802	99768	08542	99635	6
55	01600	99987	03345	99944	05088	99870	06831	99766	08571	99632	5
56	01629	99987	03374	99943	05117	99869	06860	99764	08600	99630	4
57	01658	99986	03403	99942	05146	99867	06889	99762	08629	99627	3
58	01687	99986	03432	99941	05175	99866	06918	99760	08658	99625	2
59	01716	99985	03461	99940	05205	99864	06947	99758	08687	99622	1
60	01745	99985	03490	99939	05234	99863	06976	99756	08716	99619	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	89°		88°		87°		86°		85°		

TABLE X.—SINES AND COSINES.

	5°		6°		7°		8°		9°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	08716	99619	10458	99452	12187	99255	13917	99027	15643	98769	60
1	08745	99617	10482	99449	12216	99251	13946	99023	15672	98764	59
2	08774	99614	10511	99446	12245	99248	13975	99019	15701	98760	58
3	08803	99612	10540	99443	12274	99244	14004	99015	15730	98755	57
4	08831	99609	10569	99440	12302	99240	14033	99011	15758	98751	56
5	08860	99607	10597	99437	12331	99237	14061	99006	15787	98746	55
6	08889	99604	10626	99434	12360	99233	14090	99002	15816	98741	54
7	08918	99602	10655	99431	12389	99230	14119	98998	15845	98737	53
8	08947	99599	10684	99428	12418	99226	14148	98994	15873	98732	52
9	08976	99596	10713	99424	12447	99222	14177	98990	15902	98728	51
10	09005	99594	10742	99421	12476	99219	14205	98986	15931	98723	50
11	09034	99591	10771	99418	12504	99215	14234	98982	15959	98718	49
12	09063	99588	10800	99415	12533	99211	14263	98978	15988	98714	48
13	09092	99586	10829	99412	12562	99208	14292	98973	16017	98709	47
14	09121	99583	10858	99409	12591	99204	14320	98969	16046	98704	46
15	09150	99580	10887	99406	12620	99200	14349	98965	16074	98700	45
16	09179	99578	10916	99402	12649	99197	14378	98961	16103	98695	44
17	09208	99575	10945	99399	12678	99193	14407	98957	16132	98690	43
18	09237	99572	10973	99396	12706	99189	14436	98953	16160	98686	42
19	09266	99570	11002	99393	12735	99186	14464	98948	16189	98681	41
20	09295	99567	11031	99390	12764	99182	14493	98944	16218	98676	40
21	09324	99564	11060	99386	12793	99178	14522	98940	16246	98671	39
22	09353	99562	11089	99383	12822	99175	14551	98936	16275	98667	38
23	09382	99559	11118	99380	12851	99171	14580	98931	16304	98662	37
24	09411	99556	11147	99377	12880	99167	14608	98927	16333	98657	36
25	09440	99553	11176	99374	12908	99163	14637	98923	16361	98652	35
26	09469	99551	11205	99370	12937	99160	14666	98919	16390	98648	34
27	09498	99548	11234	99367	12966	99156	14695	98914	16419	98643	33
28	09527	99545	11263	99364	12995	99152	14723	98910	16447	98638	32
29	09556	99542	11291	99360	13024	99148	14752	98906	16476	98633	31
30	09585	99540	11320	99357	13053	99144	14781	98902	16505	98629	30
31	09614	99537	11349	99354	13081	99141	14810	98897	16533	98624	29
32	09642	99534	11378	99351	13110	99137	14838	98893	16562	98619	28
33	09671	99531	11407	99347	13139	99133	14867	98889	16591	98614	27
34	09700	99528	11436	99344	13168	99129	14896	98884	16620	98609	26
35	09729	99526	11465	99341	13197	99125	14925	98880	16648	98604	25
36	09758	99523	11494	99337	13226	99122	14954	98876	16677	98600	24
37	09787	99520	11523	99334	13254	99118	14982	98871	16706	98595	23
38	09816	99517	11552	99331	13283	99114	15011	98867	16734	98590	22
39	09845	99514	11580	99327	13312	99110	15040	98863	16763	98585	21
40	09874	99511	11609	99324	13341	99106	15069	98858	16792	98580	20
41	09903	99508	11638	99320	13370	99102	15097	98854	16820	98575	19
42	09932	99506	11667	99317	13399	99098	15126	98849	16849	98570	18
43	09961	99503	11696	99314	13427	99094	15155	98845	16878	98565	17
44	09990	99500	11725	99310	13456	99091	15184	98841	16906	98561	16
45	10019	99497	11754	99307	13485	99087	15212	98836	16935	98556	15
46	10048	99494	11783	99303	13514	99083	15241	98832	16964	98551	14
47	10077	99491	11812	99300	13543	99079	15270	98827	16992	98546	13
48	10106	99488	11840	99297	13572	99075	15299	98823	17021	98541	12
49	10135	99485	11869	99293	13600	99071	15327	98818	17050	98536	11
50	10164	99482	11898	99290	13629	99067	15356	98814	17078	98531	10
51	10192	99479	11927	99286	13658	99063	15385	98809	17107	98526	9
52	10221	99476	11956	99283	13687	99059	15414	98805	17136	98521	8
53	10250	99473	11985	99279	13716	99055	15442	98800	17164	98516	7
54	10279	99470	12014	99276	13744	99051	15471	98796	17193	98511	6
55	10308	99467	12043	99272	13773	99047	15500	98791	17222	98506	5
56	10337	99464	12071	99269	13802	99043	15529	98787	17250	98501	4
57	10366	99461	12100	99265	13831	99039	15557	98782	17279	98496	3
58	10395	99458	12129	99262	13860	99035	15586	98778	17308	98491	2
59	10424	99455	12158	99258	13889	99031	15615	98773	17336	98486	1
60	10453	99452	12187	99255	13917	99027	15643	98769	17365	98481	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	84°		83°		82°		81°		80°		

TABLE X.—SINES AND COSINES.

	10°		11°		12°		13°		14°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	17365	98481	19061	98163	20791	97815	22495	97437	24192	97030	60
1	17398	98476	19109	98157	20820	97809	22523	97430	24220	97023	59
2	17422	98471	19136	98152	20848	97803	22552	97424	24249	97015	58
3	17451	98466	19167	98146	20877	97797	22580	97417	24277	97008	57
4	17479	98461	19195	98140	20905	97791	22608	97411	24305	97001	56
5	17508	98455	19224	98135	20933	97784	22637	97404	24333	96994	55
6	17537	98450	19252	98129	20962	97778	22665	97398	24362	96987	54
7	17565	98445	19281	98124	20990	97772	22693	97391	24390	96980	53
8	17594	98440	19309	98118	21019	97766	22722	97384	24418	96973	52
9	17623	98435	19338	98112	21047	97760	22750	97378	24446	96966	51
10	17651	98430	19366	98107	21076	97754	22778	97371	24474	96959	50
11	17680	98425	19395	98101	21104	97748	22807	97365	24503	96952	49
12	17708	98420	19423	98096	21132	97742	22835	97358	24531	96945	48
13	17737	98414	19452	98090	21161	97735	22863	97351	24559	96937	47
14	17766	98409	19481	98084	21189	97729	22892	97345	24587	96930	46
15	17794	98404	19509	98079	21218	97723	22920	97338	24615	96923	45
16	17823	98399	19538	98073	21246	97717	22948	97331	24644	96916	44
17	17852	98394	19566	98067	21275	97711	22977	97325	24672	96909	43
18	17880	98389	19595	98061	21303	97705	23005	97318	24700	96902	42
19	17909	98383	19623	98056	21331	97698	23033	97311	24728	96894	41
20	17937	98378	19652	98050	21360	97692	23062	97304	24756	96887	40
21	17966	98373	19680	98044	21388	97686	23090	97298	24784	96880	39
22	17995	98368	19709	98039	21417	97680	23118	97291	24813	96873	38
23	18023	98362	19737	98033	21445	97673	23146	97284	24841	96866	37
24	18052	98357	19766	98027	21474	97667	23175	97278	24869	96858	36
25	18081	98352	19794	98021	21502	97661	23203	97271	24897	96851	35
26	18109	98347	19823	98016	21530	97655	23231	97264	24925	96844	34
27	18138	98341	19851	98010	21558	97648	23260	97257	24954	96837	33
28	18166	98336	19880	98004	21587	97642	23288	97251	24982	96830	32
29	18195	98331	19908	97998	21616	97636	23316	97244	25010	96822	31
30	18224	98325	19937	97992	21644	97630	23345	97237	25038	96815	30
31	18252	98320	19965	97987	21672	97623	23373	97230	25066	96807	29
32	18281	98315	19994	97981	21701	97617	23401	97223	25094	96800	28
33	18309	98310	20022	97975	21729	97611	23429	97217	25122	96793	27
34	18338	98304	20051	97969	21758	97604	23458	97210	25151	96786	26
35	18367	98299	20079	97963	21786	97598	23486	97203	25179	96778	25
36	18395	98294	20108	97958	21814	97592	23514	97196	25207	96771	24
37	18424	98288	20136	97952	21843	97585	23542	97189	25235	96764	23
38	18452	98283	20165	97946	21871	97579	23571	97182	25263	96756	22
39	18481	98277	20193	97940	21899	97573	23599	97176	25291	96749	21
40	18509	98272	20222	97934	21928	97566	23627	97169	25320	96742	20
41	18538	98267	20250	97928	21956	97560	23656	97162	25348	96734	19
42	18567	98261	20279	97922	21985	97553	23684	97155	25376	96727	18
43	18595	98256	20307	97916	22013	97547	23712	97148	25404	96719	17
44	18624	98250	20336	97910	22041	97541	23740	97141	25432	96712	16
45	18652	98245	20364	97905	22070	97534	23769	97134	25460	96705	15
46	18681	98240	20393	97899	22098	97528	23797	97127	25488	96697	14
47	18710	98234	20421	97893	22126	97521	23825	97120	25516	96690	13
48	18738	98229	20450	97887	22155	97515	23853	97113	25545	96682	12
49	18767	98223	20478	97881	22183	97508	23882	97106	25573	96675	11
50	18795	98218	20507	97875	22212	97502	23910	97100	25601	96667	10
51	18824	98212	20535	97869	22240	97496	23938	97093	25629	96660	9
52	18852	98207	20563	97863	22268	97489	23966	97086	25657	96653	8
53	18881	98201	20592	97857	22297	97483	23995	97079	25685	96645	7
54	18910	98196	20620	97851	22325	97476	24023	97072	25713	96638	6
55	18938	98190	20649	97845	22353	97470	24051	97065	25741	96630	5
56	18967	98185	20677	97839	22382	97463	24079	97058	25769	96623	4
57	18995	98179	20706	97833	22410	97457	24108	97051	25798	96615	3
58	19024	98174	20734	97827	22438	97450	24136	97044	25826	96608	2
59	19052	98168	20763	97821	22467	97444	24164	97037	25854	96600	1
60	19061	98163	20791	97815	22495	97437	24192	97030	25882	96593	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	79°		78°		77°		76°		75°		

TABLE X.—SINES AND COSINES.

	15°		16°		17°		18°		19°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	25882	96593	27564	96126	29237	95630	30902	95106	32557	94552	60
1	25910	96585	27592	96118	29265	95622	30929	95097	32584	94542	59
2	25938	96578	27620	96110	29293	95613	30957	95088	32612	94533	58
3	25966	96570	27648	96102	29321	95605	30985	95079	32639	94523	57
4	25994	96562	27676	96094	29348	95596	31012	95070	32667	94514	56
5	26022	96555	27704	96086	29376	95588	31040	95061	32694	94504	55
6	26050	96547	27731	96078	29404	95579	31068	95052	32722	94495	54
7	26079	96540	27759	96070	29432	95571	31095	95043	32749	94485	53
8	26107	96532	27787	96062	29460	95562	31123	95033	32777	94476	52
9	26135	96524	27815	96054	29487	95554	31151	95024	32804	94466	51
10	26163	96517	27843	96046	29515	95545	31178	95015	32832	94457	50
11	26191	96509	27871	96037	29543	95536	31206	95006	32859	94447	49
12	26219	96502	27899	96029	29571	95528	31233	94997	32887	94438	48
13	26247	96494	27927	96021	29599	95519	31261	94988	32914	94428	47
14	26275	96486	27955	96013	29626	95511	31289	94979	32942	94418	46
15	26303	96479	27983	96005	29654	95502	31316	94970	32969	94409	45
16	26331	96471	28011	95997	29682	95493	31344	94961	32997	94399	44
17	26359	96463	28039	95989	29710	95485	31372	94952	33024	94390	43
18	26387	96455	28067	95981	29737	95476	31399	94943	33051	94380	42
19	26415	96448	28095	95972	29765	95467	31427	94933	33079	94370	41
20	26443	96440	28123	95964	29793	95459	31454	94924	33106	94361	40
21	26471	96433	28150	95956	29821	95450	31482	94915	33134	94351	39
22	26500	96425	28178	95948	29849	95441	31510	94906	33161	94342	38
23	26528	96417	28206	95940	29876	95433	31537	94897	33189	94332	37
24	26556	96410	28234	95931	29904	95424	31565	94888	33216	94322	36
25	26584	96402	28262	95923	29932	95415	31593	94878	33244	94313	35
26	26612	96394	28290	95915	29960	95407	31620	94869	33271	94303	34
27	26640	96386	28318	95907	29987	95398	31648	94860	33298	94293	33
28	26668	96379	28346	95898	30015	95389	31675	94851	33326	94284	32
29	26696	96371	28374	95890	30043	95380	31703	94842	33353	94274	31
30	26724	96363	28402	95882	30071	95372	31730	94832	33381	94264	30
31	26752	96355	28429	95874	30098	95363	31758	94823	33408	94254	29
32	26780	96347	28457	95865	30126	95354	31786	94814	33436	94245	28
33	26808	96340	28485	95857	30154	95345	31813	94805	33463	94235	27
34	26836	96332	28513	95849	30182	95337	31841	94795	33490	94225	26
35	26864	96324	28541	95841	30209	95328	31868	94786	33518	94215	25
36	26892	96316	28569	95832	30237	95319	31896	94777	33545	94206	24
37	26920	96308	28597	95824	30265	95310	31923	94768	33573	94196	23
38	26948	96301	28625	95816	30292	95301	31951	94758	33600	94186	22
39	26976	96293	28652	95807	30320	95292	31979	94749	33627	94176	21
40	27004	96285	28680	95799	30348	95284	32006	94740	33655	94167	20
41	27032	96277	28708	95791	30376	95275	32034	94730	33682	94157	19
42	27060	96269	28736	95782	30403	95266	32061	94721	33710	94147	18
43	27088	96261	28764	95774	30431	95257	32089	94712	33737	94137	17
44	27116	96253	28792	95766	30459	95248	32116	94702	33764	94127	16
45	27144	96245	28820	95757	30486	95240	32144	94693	33792	94118	15
46	27172	96238	28847	95749	30514	95231	32171	94684	33819	94108	14
47	27200	96230	28875	95740	30542	95222	32199	94674	33846	94098	13
48	27228	96222	28903	95732	30570	95213	32227	94665	33874	94088	12
49	27256	96214	28931	95724	30597	95204	32254	94656	33901	94078	11
50	27284	96206	28959	95715	30625	95195	32282	94646	33929	94068	10
51	27312	96198	28987	95707	30653	95186	32309	94637	33956	94058	9
52	27340	96190	29015	95698	30680	95177	32337	94627	33983	94049	8
53	27368	96182	29042	95690	30708	95168	32364	94618	34011	94039	7
54	27396	96174	29070	95681	30736	95159	32392	94609	34038	94029	6
55	27424	96166	29098	95673	30763	95150	32419	94599	34065	94019	5
56	27452	96158	29126	95664	30791	95142	32447	94590	34093	94009	4
57	27480	96150	29154	95656	30819	95133	32474	94580	34120	93999	3
58	27508	96142	29182	95647	30846	95124	32502	94571	34147	93989	2
59	27536	96134	29209	95639	30874	95115	32529	94561	34175	93979	1
60	27564	96126	29237	95630	30902	95106	32557	94552	34202	93969	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	74°		73°		72°		71°		70°		

TABLE X.—SINES AND COSINES.

	20°		21°		22°		23°		24°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	34202	99969	35887	99858	37461	99718	39073	92050	40674	91855	60
1	34229	99959	35864	99848	37488	92707	39100	92039	40700	91843	59
2	34257	99949	35891	99837	37515	92697	39127	92028	40727	91831	58
3	34284	99939	35918	99827	37542	92686	39153	92016	40753	91819	57
4	34311	99929	35945	99816	37569	92675	39180	92005	40780	91807	56
5	34339	99919	35973	99806	37595	92664	39207	91994	40806	91795	55
6	34366	99909	36000	99795	37622	92653	39234	91982	40833	91783	54
7	34393	99899	36027	99785	37649	92642	39260	91971	40860	91772	53
8	34421	99889	36054	99774	37676	92631	39287	91959	40886	91760	52
9	34448	99879	36081	99764	37703	92620	39314	91948	40913	91748	51
10	34475	99869	36108	99753	37730	92609	39341	91936	40939	91736	50
11	34503	99859	36135	99743	37757	92598	39367	91925	40966	91724	49
12	34530	99849	36162	99732	37784	92587	39394	91914	40992	91712	48
13	34557	99839	36190	99722	37811	92576	39421	91902	41019	91700	47
14	34584	99829	36217	99711	37838	92565	39448	91891	41045	91688	46
15	34612	99819	36244	99701	37865	92554	39474	91879	41072	91676	45
16	34639	99809	36271	99690	37892	92543	39501	91868	41098	91664	44
17	34666	99799	36298	99680	37919	92532	39528	91856	41125	91652	43
18	34694	99789	36325	99670	37946	92521	39555	91845	41151	91640	42
19	34721	99779	36352	99659	37973	92510	39581	91833	41178	91628	41
20	34748	99769	36379	99648	37999	92499	39608	91822	41204	91616	40
21	34775	99759	36406	99637	38026	92488	39635	91810	41231	91604	39
22	34803	99748	36433	99627	38053	92477	39661	91799	41257	91592	38
23	34830	99738	36461	99616	38080	92466	39688	91787	41284	91580	37
24	34857	99728	36488	99606	38107	92455	39715	91775	41310	91568	36
25	34884	99718	36515	99595	38134	92444	39741	91764	41337	91556	35
26	34912	99708	36542	99584	38161	92432	39768	91752	41363	91544	34
27	34939	99698	36569	99574	38188	92421	39795	91741	41390	91532	33
28	34966	99688	36596	99563	38215	92410	39822	91729	41416	91520	32
29	34993	99677	36623	99552	38241	92399	39848	91718	41443	91508	31
30	35021	99667	36650	99542	38268	92388	39875	91706	41469	91496	30
31	35048	99657	36677	99531	38295	92377	39902	91694	41496	91484	29
32	35075	99647	36704	99520	38322	92366	39928	91683	41522	91472	28
33	35102	99637	36731	99510	38349	92355	39955	91671	41549	91460	27
34	35130	99626	36758	99500	38376	92343	39982	91660	41575	91448	26
35	35157	99616	36785	99489	38403	92332	40008	91648	41602	91436	25
36	35184	99606	36812	99478	38430	92321	40035	91636	41628	91424	24
37	35211	99596	36839	99467	38456	92310	40062	91625	41655	91412	23
38	35239	99585	36867	99456	38483	92299	40088	91613	41681	91400	22
39	35266	99575	36894	99445	38510	92287	40115	91601	41707	91388	21
40	35293	99565	36921	99434	38537	92276	40141	91590	41734	91376	20
41	35320	99555	36948	99424	38564	92265	40168	91578	41760	91364	19
42	35347	99544	36975	99413	38591	92254	40195	91566	41787	91352	18
43	35375	99534	37002	99402	38617	92243	40221	91555	41813	91340	17
44	35402	99524	37029	99392	38644	92231	40248	91543	41840	91328	16
45	35429	99514	37056	99381	38671	92220	40275	91531	41866	91316	15
46	35456	99503	37083	99370	38698	92209	40301	91519	41892	91304	14
47	35484	99493	37110	99359	38725	92198	40328	91508	41919	91292	13
48	35511	99483	37137	99348	38752	92186	40355	91496	41945	91280	12
49	35538	99473	37164	99337	38778	92175	40381	91484	41972	91268	11
50	35565	99462	37191	99327	38805	92164	40408	91472	41998	91256	10
51	35592	99452	37218	99316	38832	92153	40434	91461	42024	91244	9
52	35619	99441	37245	99305	38859	92141	40461	91449	42051	91232	8
53	35647	99431	37272	99294	38886	92130	40488	91437	42077	91220	7
54	35674	99420	37299	99284	38912	92119	40514	91425	42104	91208	6
55	35701	99410	37326	99273	38939	92107	40541	91414	42130	91196	5
56	35728	99400	37353	99262	38966	92096	40567	91402	42156	91184	4
57	35755	99389	37380	99251	38993	92085	40594	91390	42183	91172	3
58	35782	99379	37407	99240	39020	92073	40621	91378	42209	91160	2
59	35810	99368	37434	99229	39046	92062	40647	91366	42235	91148	1
60	35837	99358	37461	99218	39073	92050	40674	91355	42262	91136	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	69°		68°		67°		66°		65°		

TABLE X.—SINES AND COSINES.

	25°		26°		27°		28°		29°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	42262	90631	42837	89879	45399	89101	46947	88295	48481	87462	60
1	42268	90618	42863	89867	45425	89087	46973	88281	48506	87448	59
2	42275	90606	42889	89854	45451	89074	46999	88267	48532	87434	58
3	42281	90594	42916	89841	45477	89061	47024	88254	48557	87420	57
4	42287	90582	42942	89828	45503	89048	47050	88240	48583	87406	56
5	42294	90569	42968	89816	45529	89035	47076	88226	48608	87391	55
6	42300	90557	42994	89803	45554	89021	47101	88213	48634	87377	54
7	42346	90545	43020	89790	45580	89008	47127	88199	48659	87363	53
8	42373	90532	43046	89777	45606	88995	47153	88185	48684	87349	52
9	42399	90520	43072	89764	45632	88981	47178	88172	48710	87335	51
10	42525	90507	43098	89752	45658	88968	47204	88158	48735	87321	50
11	42552	90495	43124	89739	45684	88955	47229	88144	48761	87306	49
12	42578	90483	43151	89726	45710	88942	47255	88130	48786	87292	48
13	42604	90470	43177	89713	45736	88928	47281	88117	48811	87278	47
14	42631	90458	43203	89700	45762	88915	47306	88103	48837	87264	46
15	42657	90446	43229	89687	45787	88902	47332	88089	48862	87250	45
16	42683	90433	43255	89674	45813	88888	47358	88075	48888	87235	44
17	42709	90421	43281	89662	45839	88875	47383	88062	48913	87221	43
18	42736	90408	43307	89649	45865	88862	47409	88048	48938	87207	42
19	42762	90396	43333	89636	45891	88848	47434	88034	48964	87193	41
20	42788	90383	43359	89623	45917	88835	47460	88020	48989	87178	40
21	42815	90371	43385	89610	45942	88822	47486	88006	49014	87164	39
22	42841	90358	43411	89597	45968	88808	47511	87993	49040	87150	38
23	42867	90346	43437	89584	45994	88795	47537	87979	49065	87136	37
24	42894	90334	43464	89571	46020	88782	47562	87965	49090	87121	36
25	42920	90321	43490	89558	46046	88768	47588	87951	49116	87107	35
26	42946	90309	43516	89545	46072	88755	47614	87937	49141	87093	34
27	42972	90296	43542	89532	46097	88741	47639	87923	49166	87079	33
28	42999	90284	43568	89519	46123	88728	47665	87909	49192	87064	32
29	43025	90271	43594	89506	46149	88715	47690	87896	49217	87050	31
30	43051	90259	43620	89493	46175	88701	47716	87882	49242	87036	30
31	43077	90246	43646	89480	46201	88688	47741	87868	49268	87021	29
32	43104	90233	43672	89467	46226	88674	47767	87854	49293	87007	28
33	43130	90221	43698	89454	46252	88661	47792	87840	49318	86993	27
34	43156	90208	43724	89441	46278	88647	47818	87826	49344	86978	26
35	43182	90196	43750	89428	46304	88634	47844	87812	49369	86964	25
36	43209	90183	43776	89415	46330	88620	47869	87798	49394	86949	24
37	43235	90171	43802	89402	46355	88607	47895	87784	49419	86935	23
38	43261	90158	43828	89389	46381	88593	47920	87770	49445	86921	22
39	43287	90146	43854	89376	46407	88580	47946	87756	49470	86906	21
40	43313	90133	43880	89363	46433	88566	47971	87743	49495	86892	20
41	43340	90120	43906	89350	46458	88553	47997	87729	49521	86878	19
42	43366	90108	43932	89337	46484	88539	48022	87715	49546	86863	18
43	43392	90095	43958	89324	46510	88526	48048	87701	49571	86849	17
44	43418	90082	43984	89311	46536	88512	48073	87687	49596	86834	16
45	43445	90070	44010	89298	46561	88499	48099	87673	49622	86820	15
46	43471	90057	44036	89285	46587	88485	48124	87659	49647	86805	14
47	43497	90045	44062	89272	46613	88472	48150	87645	49672	86791	13
48	43523	90032	44088	89259	46639	88458	48175	87631	49697	86777	12
49	43549	90019	44114	89245	46664	88445	48201	87617	49722	86762	11
50	43575	90007	44140	89232	46690	88431	48226	87603	49748	86748	10
51	43602	89994	44166	89219	46716	88417	48252	87589	49773	86733	9
52	43628	89981	44192	89206	46742	88404	48277	87575	49798	86719	8
53	43654	89968	44218	89193	46767	88390	48303	87561	49824	86704	7
54	43680	89956	44243	89180	46793	88377	48328	87546	49849	86690	6
55	43706	89943	44269	89167	46819	88363	48354	87532	49874	86675	5
56	43732	89930	44295	89153	46844	88349	48379	87518	49899	86661	4
57	43759	89918	44321	89140	46870	88336	48405	87504	49924	86646	3
58	43785	89905	44347	89127	46896	88322	48430	87490	49950	86632	2
59	43811	89892	44373	89114	46921	88308	48456	87476	49975	86617	1
60	43837	89879	44399	89101	46947	88295	48481	87462	50000	86603	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	64°		63°		62°		61°		60°		

TABLE X.—SINES AND COSINES.

	30°		31°		32°		33°		34°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	50000	86603	51504	85717	52992	84805	54464	83867	55919	82904	60
1	50025	86588	51529	85702	53017	84789	54488	83851	55943	82887	59
2	50050	86573	51554	85687	53041	84774	54513	83835	55968	82871	58
3	50076	86559	51579	85672	53066	84759	54537	83819	55992	82855	57
4	50101	86544	51604	85657	53091	84743	54561	83804	56016	82839	56
5	50126	86530	51628	85642	53115	84728	54586	83788	56040	82822	55
6	50151	86515	51653	85627	53140	84712	54610	83772	56064	82806	54
7	50176	86501	51678	85612	53164	84697	54635	83756	56088	82790	53
8	50201	86486	51703	85597	53189	84681	54659	83740	56112	82773	52
9	50227	86471	51728	85582	53214	84666	54683	83724	56136	82757	51
10	50252	86457	51753	85567	53238	84650	54708	83708	56160	82741	50
11	50277	86442	51778	85551	53263	84635	54732	83692	56184	82724	49
12	50302	86427	51803	85536	53288	84619	54756	83676	56208	82708	48
13	50327	86413	51828	85521	53312	84604	54781	83660	56232	82692	47
14	50352	86398	51853	85506	53337	84588	54805	83645	56256	82675	46
15	50377	86384	51877	85491	53361	84573	54829	83629	56280	82659	45
16	50403	86369	51902	85476	53386	84557	54854	83613	56305	82643	44
17	50428	86354	51927	85461	53411	84542	54878	83597	56329	82626	43
18	50453	86340	51952	85446	53435	84526	54902	83581	56353	82610	42
19	50478	86325	51977	85431	53460	84511	54927	83565	56377	82593	41
20	50503	86310	52002	85416	53484	84495	54951	83549	56401	82577	40
21	50528	86295	52026	85401	53509	84480	54975	83533	56425	82561	39
22	50553	86281	52051	85385	53534	84464	54999	83517	56449	82544	38
23	50578	86266	52076	85370	53558	84448	55024	83501	56473	82528	37
24	50603	86251	52101	85355	53583	84433	55048	83485	56497	82511	36
25	50628	86237	52126	85340	53607	84417	55072	83469	56521	82495	35
26	50654	86222	52151	85325	53632	84402	55097	83453	56545	82478	34
27	50679	86207	52175	85310	53656	84386	55121	83437	56569	82462	33
28	50704	86192	52200	85294	53681	84370	55145	83421	56593	82446	32
29	50729	86178	52225	85279	53705	84355	55169	83405	56617	82429	31
30	50754	86163	52250	85264	53730	84339	55194	83389	56641	82413	30
31	50779	86148	52275	85249	53754	84324	55218	83373	56665	82396	29
32	50804	86133	52299	85234	53779	84308	55242	83356	56689	82380	28
33	50829	86119	52324	85218	53804	84292	55266	83340	56713	82363	27
34	50854	86104	52349	85203	53828	84277	55291	83324	56738	82347	26
35	50879	86089	52374	85188	53853	84261	55315	83308	56760	82330	25
36	50904	86074	52399	85173	53877	84245	55339	83292	56784	82314	24
37	50929	86059	52423	85157	53902	84230	55363	83276	56808	82297	23
38	50954	86045	52448	85142	53926	84214	55388	83260	56832	82281	22
39	50979	86030	52473	85127	53951	84198	55412	83244	56856	82264	21
40	51004	86015	52498	85112	53975	84182	55436	83228	56880	82248	20
41	51029	86000	52522	85096	54000	84167	55460	83212	56904	82231	19
42	51054	85985	52547	85081	54024	84151	55484	83195	56928	82214	18
43	51079	85970	52572	85066	54049	84135	55509	83179	56952	82198	17
44	51104	85956	52597	85051	54073	84120	55533	83163	56976	82181	16
45	51129	85941	52621	85035	54097	84104	55557	83147	57000	82165	15
46	51154	85926	52646	85020	54122	84088	55581	83131	57024	82148	14
47	51179	85911	52671	85005	54146	84072	55605	83115	57047	82132	13
48	51204	85896	52696	84989	54171	84057	55630	83098	57071	82115	12
49	51229	85881	52720	84974	54195	84041	55654	83082	57095	82098	11
50	51254	85866	52745	84959	54220	84025	55678	83066	57119	82082	10
51	51279	85851	52770	84943	54244	84009	55702	83050	57143	82065	9
52	51304	85836	52794	84928	54269	83994	55726	83034	57167	82048	8
53	51329	85821	52819	84913	54293	83978	55750	83017	57191	82032	7
54	51354	85806	52844	84897	54317	83962	55775	83001	57215	82015	6
55	51379	85792	52869	84882	54342	83946	55799	82985	57238	81999	5
56	51404	85777	52893	84866	54366	83930	55823	82969	57262	81983	4
57	51429	85762	52918	84851	54391	83915	55847	82953	57286	81965	3
58	51454	85747	52943	84836	54415	83899	55871	82936	57310	81949	2
59	51479	85732	52967	84820	54440	83883	55895	82920	57334	81932	1
60	51504	85717	52992	84805	54464	83867	55919	82904	57358	81915	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	59°		58°		57°		56°		55°		

TABLE X.—SINES AND COSINES.

	35°		36°		37°		38°		39°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	57358	81915	58779	80902	60182	79864	61566	78801	62982	77715	60
1	57381	81899	58802	80885	60205	79846	61589	78783	62955	77696	59
2	57405	81882	58826	80867	60228	79829	61612	78765	62977	77678	58
3	57429	81865	58849	80850	60251	79811	61635	78747	63000	77660	57
4	57453	81848	58873	80833	60274	79793	61658	78729	63022	77641	56
5	57477	81832	58896	80816	60298	79776	61681	78711	63045	77623	55
6	57501	81815	58920	80799	60321	79758	61704	78694	63068	77605	54
7	57524	81798	58943	80782	60344	79741	61726	78676	63090	77586	53
8	57548	81782	58967	80765	60367	79723	61749	78658	63113	77568	52
9	57572	81765	58990	80748	60390	79706	61772	78640	63135	77550	51
10	57596	81748	59014	80730	60414	79688	61795	78622	63158	77531	50
11	57619	81731	59037	80713	60437	79671	61818	78604	63180	77513	49
12	57643	81714	59061	80696	60460	79653	61841	78586	63203	77494	48
13	57667	81698	59084	80679	60483	79635	61864	78568	63225	77476	47
14	57691	81681	59108	80662	60506	79618	61887	78550	63248	77458	46
15	57715	81664	59131	80644	60529	79600	61909	78532	63271	77439	45
16	57738	81647	59154	80627	60553	79583	61932	78514	63293	77421	44
17	57762	81631	59178	80610	60576	79565	61955	78496	63316	77402	43
18	57786	81614	59201	80593	60599	79547	61978	78478	63338	77384	42
19	57810	81597	59225	80576	60622	79530	62001	78460	63361	77366	41
20	57833	81580	59248	80558	60645	79512	62024	78442	63383	77347	40
21	57857	81563	59272	80541	60668	79494	62046	78424	63406	77329	39
22	57881	81546	59295	80524	60691	79477	62069	78405	63428	77310	38
23	57904	81530	59318	80507	60714	79459	62092	78387	63451	77292	37
24	57928	81513	59342	80489	60738	79441	62115	78369	63473	77273	36
25	57952	81496	59365	80472	60761	79424	62138	78351	63496	77255	35
26	57976	81479	59389	80455	60784	79406	62160	78333	63518	77236	34
27	57999	81462	59412	80438	60807	79388	62183	78315	63540	77218	33
28	58023	81445	59436	80420	60830	79371	62206	78297	63563	77199	32
29	58047	81428	59459	80403	60853	79353	62229	78279	63585	77181	31
30	58070	81412	59482	80386	60876	79335	62251	78261	63608	77162	30
31	58094	81395	59506	80368	60899	79318	62274	78243	63630	77144	29
32	58118	81378	59529	80351	60922	79300	62297	78225	63653	77125	28
33	58141	81361	59552	80334	60945	79282	62320	78206	63675	77107	27
34	58165	81344	59576	80316	60968	79264	62342	78188	63698	77088	26
35	58189	81327	59599	80299	60991	79247	62365	78170	63720	77070	25
36	58212	81310	59623	80282	61015	79229	62388	78152	63742	77051	24
37	58236	81293	59646	80264	61038	79211	62411	78134	63765	77033	23
38	58260	81276	59669	80247	61061	79193	62433	78116	63787	77014	22
39	58283	81259	59693	80230	61084	79176	62456	78098	63810	76996	21
40	58307	81242	59716	80212	61107	79158	62479	78079	63832	76977	20
41	58330	81225	59739	80195	61130	79140	62502	78061	63854	76959	19
42	58354	81208	59763	80178	61153	79122	62524	78043	63877	76940	18
43	58378	81191	59786	80160	61176	79105	62547	78025	63899	76921	17
44	58401	81174	59809	80143	61199	79087	62570	78007	63922	76903	16
45	58425	81157	59832	80125	61222	79069	62592	77988	63944	76884	15
46	58449	81140	59856	80108	61245	79051	62615	77970	63966	76866	14
47	58472	81123	59879	80091	61268	79033	62638	77952	63989	76847	13
48	58496	81106	59902	80073	61291	79016	62660	77934	64011	76828	12
49	58519	81089	59926	80056	61314	78998	62683	77916	64033	76810	11
50	58543	81072	59949	80038	61337	78980	62706	77897	64056	76791	10
51	58567	81055	59972	80021	61360	78962	62728	77879	64078	76772	9
52	58590	81038	59995	80003	61383	78944	62751	77861	64100	76754	8
53	58614	81021	60019	79986	61406	78926	62774	77843	64123	76735	7
54	58637	81004	60042	79968	61429	78908	62796	77824	64145	76717	6
55	58661	80987	60065	79951	61451	78891	62819	77806	64167	76698	5
56	58684	80970	60089	79934	61474	78873	62842	77788	64190	76679	4
57	58708	80953	60112	79916	61497	78855	62864	77769	64212	76661	3
58	58731	80936	60135	79899	61520	78837	62887	77751	64234	76642	2
59	58755	80919	60158	79881	61543	78819	62909	77733	64256	76623	1
60	58779	80902	60182	79864	61566	78801	62932	77715	64279	76604	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	54°		53°		52°		51°		50°		

TABLE X.—SINES AND COSINES.

	40°		41°		42°		43°		44°		
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	64279	76604	65606	75471	66913	74314	68200	73135	69466	71934	60
1	64301	76586	65628	75452	66935	74295	68221	73116	69487	71914	59
2	64323	76567	65650	75433	66956	74276	68242	73096	69508	71894	58
3	64346	76548	65672	75414	66978	74256	68264	73076	69529	71873	57
4	64368	76530	65694	75395	66999	74237	68285	73056	69549	71853	56
5	64390	76511	65716	75375	67021	74217	68306	73036	69570	71833	55
6	64412	76492	65738	75356	67043	74198	68327	73016	69591	71813	54
7	64435	76473	65759	75337	67064	74178	68349	72996	69612	71792	53
8	64457	76455	65781	75318	67086	74159	68370	72976	69633	71772	52
9	64479	76436	65803	75299	67107	74139	68391	72957	69654	71752	51
10	64501	76417	65825	75280	67129	74120	68412	72937	69675	71732	50
11	64524	76398	65847	75261	67151	74100	68434	72917	69696	71711	49
12	64546	76380	65869	75241	67172	74080	68455	72897	69717	71691	48
13	64568	76361	65891	75223	67194	74061	68476	72877	69737	71671	47
14	64590	76342	65913	75203	67215	74041	68497	72857	69758	71650	46
15	64612	76323	65935	75184	67237	74022	68518	72837	69779	71630	45
16	64635	76304	65956	75165	67258	74002	68539	72817	69800	71610	44
17	64657	76286	65978	75146	67280	73983	68561	72797	69821	71590	43
18	64679	76267	66000	75126	67301	73963	68582	72777	69842	71569	42
19	64701	76248	66022	75107	67323	73944	68603	72757	69862	71549	41
20	64723	76229	66044	75088	67344	73924	68624	72737	69883	71529	40
21	64746	76210	66066	75069	67366	73904	68645	72717	69904	71508	39
22	64768	76192	66088	75050	67387	73885	68666	72697	69925	71488	38
23	64790	76173	66109	75030	67409	73865	68688	72677	69946	71468	37
24	64812	76154	66131	75011	67430	73846	68709	72657	69966	71447	36
25	64834	76135	66153	74992	67452	73826	68730	72637	69987	71427	35
26	64856	76116	66175	74973	67473	73806	68751	72617	70008	71407	34
27	64878	76097	66197	74953	67495	73787	68772	72597	70029	71386	33
28	64901	76078	66218	74934	67516	73767	68793	72577	70049	71366	32
29	64923	76059	66240	74915	67538	73747	68814	72557	70070	71345	31
30	64945	76041	66262	74896	67559	73728	68835	72537	70091	71325	30
31	64967	76022	66284	74876	67580	73708	68857	72517	70112	71305	29
32	64989	76003	66306	74857	67602	73688	68878	72497	70132	71284	28
33	65011	75984	66327	74838	67623	73669	68899	72477	70153	71264	27
34	65033	75965	66349	74818	67645	73649	68920	72457	70174	71243	26
35	65055	75946	66371	74799	67666	73629	68941	72437	70195	71223	35
36	65077	75927	66393	74780	67688	73610	68962	72417	70215	71203	24
37	65100	75908	66414	74760	67709	73590	68983	72397	70236	71182	23
38	65122	75889	66436	74741	67730	73570	69004	72377	70257	71162	22
39	65144	75870	66458	74722	67752	73551	69025	72357	70277	71141	21
40	65166	75851	66480	74703	67773	73531	69046	72337	70298	71121	20
41	65188	75832	66501	74683	67795	73511	69067	72317	70319	71100	19
42	65210	75813	66523	74664	67816	73491	69088	72297	70339	71080	18
43	65232	75794	66545	74644	67837	73472	69109	72277	70360	71059	17
44	65254	75775	66566	74625	67859	73452	69130	72257	70381	71039	16
45	65276	75756	66588	74606	67880	73432	69151	72236	70401	71019	15
46	65298	75737	66610	74586	67901	73413	69172	72216	70422	70998	14
47	65320	75719	66632	74567	67923	73393	69193	72196	70443	70978	13
48	65342	75700	66653	74548	67944	73373	69214	72176	70463	70957	12
49	65364	75680	66675	74528	67965	73353	69235	72156	70484	70937	11
50	65386	75661	66697	74509	67987	73333	69256	72136	70505	70916	10
51	65408	75642	66718	74489	68008	73314	69277	72116	70525	70896	9
52	65430	75623	66740	74470	68029	73294	69298	72095	70546	70875	8
53	65452	75604	66762	74451	68051	73274	69319	72075	70567	70855	7
54	65474	75585	66783	74431	68072	73254	69340	72055	70587	70834	6
55	65496	75566	66805	74412	68093	73234	69361	72035	70608	70813	5
56	65518	75547	66827	74392	68115	73215	69382	72015	70628	70793	4
57	65540	75528	66848	74373	68136	73195	69403	71995	70649	70772	3
58	65562	75509	66870	74352	68157	73175	69424	71974	70670	70752	2
59	65584	75490	66891	74334	68179	73155	69445	71954	70690	70731	1
60	65606	75471	66913	74314	68200	73135	69466	71934	70711	70711	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	49°		48°		47°		46°		45°		

NATURAL SECANTS AND CO-SECANTS.

Natural Secants and Co-secants.

	0°		1°		2°		3°		
	SECANT.	CO-SECANT.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	I	Infinite.	1.0001	57.299	1.0006	28.654	1.0014	19.107	60
1	I	3437.7	.0001	6.359	.0006	8.417	.0014	9.002	59
2	I	1718.9	.0002	5.45	.0006	8.184	.0014	8.897	58
3	I	145.9	.0002	4.57	.0006	7.955	.0014	8.794	57
4	I	859.44	.0002	3.718	.0006	7.73	.0014	8.692	56
5	I	687.55	1.0002	52.891	1.0007	27.508	1.0014	18.591	55
6	I	572.96	.0002	2.09	.0007	7.29	.0015	8.491	54
7	I	491.11	.0002	1.313	.0007	7.075	.0015	8.393	53
8	I	29.72	.0002	0.558	.0007	6.864	.0015	8.295	52
9	I	381.97	.0002	49.826	.0007	6.655	.0015	8.198	51
10	I	343.77	1.0002	49.114	1.0007	26.45	1.0015	18.103	50
11	I	12.52	.0002	8.422	.0007	6.249	.0015	8.008	49
12	I	286.48	.0002	7.75	.0007	6.05	.0016	7.914	48
13	I	64.44	.0002	7.096	.0007	5.854	.0016	7.821	47
14	I	45.55	.0002	6.46	.0008	5.661	.0016	7.73	46
15	I	229.18	1.0002	45.84	1.0008	25.471	1.0016	17.639	45
16	I	14.86	.0002	5.237	.0008	5.284	.0016	7.549	44
17	I	02.22	.0002	4.65	.0008	5.1	.0016	7.46	43
18	I	190.99	.0002	4.077	.0008	4.918	.0017	7.372	42
19	I	80.73	.0003	3.52	.0008	4.739	.0017	7.285	41
20	I	171.89	1.0003	42.976	1.0008	24.562	1.0017	17.198	40
21	I	63.7	.0003	2.445	.0008	4.358	.0017	7.113	39
22	I	56.26	.0003	1.928	.0008	4.216	.0017	7.028	38
23	I	49.47	.0003	1.423	.0009	4.047	.0017	6.944	37
24	I	43.24	.0003	40.93	.0009	3.88	.0018	6.861	36
25	I	137.51	1.0003	40.448	1.0009	23.716	1.0018	16.779	35
26	I	32.22	.0003	39.978	.0009	3.553	.0018	6.698	34
27	I	27.32	.0003	9.518	.0009	3.393	.0018	6.617	33
28	I	22.78	.0003	9.069	.0009	3.235	.0018	6.538	32
29	I	18.54	.0003	8.631	.0009	3.079	.0018	6.459	31
30	I	114.59	1.0003	38.201	1.0009	22.925	1.0019	16.38	30
31	I	10.9	.0003	7.782	.001	2.774	.0019	6.303	29
32	I	07.43	.0003	7.371	.001	2.624	.0019	6.226	28
33	I	04.17	.0004	6.969	.001	2.476	.0019	6.15	27
34	I	01.11	.0004	6.576	.001	2.33	.0019	6.075	26
35	I	98.223	1.0004	36.191	1.001	22.186	1.0019	16	25
36	I	5.495	.0004	5.814	.001	2.044	.002	5.926	24
37	I	2.914	.0004	5.445	.001	1.904	.002	5.853	23
38	1.0001	2.469	.0004	5.084	.001	1.765	.002	5.78	22
39	.0001	88.149	.0004	4.729	.0011	1.629	.002	5.708	21
40	1.0001	85.946	1.0004	34.382	1.0011	21.494	1.002	15.637	20
41	.0001	3.849	.0004	4.042	.0011	1.36	.0021	5.566	19
42	.0001	1.853	.0004	3.708	.0011	1.228	.0021	5.496	18
43	.0001	79.95	.0004	3.381	.0011	1.098	.0021	5.427	17
44	.0001	8.133	.0004	3.06	.0011	20.97	.0021	5.358	16
45	1.0001	76.396	1.0005	32.745	1.0011	20.843	1.0021	15.29	15
46	.0001	4.736	.0005	2.437	.0012	0.717	.0022	5.222	14
47	.0001	3.146	.0005	2.134	.0012	0.593	.0022	5.155	13
48	.0001	1.622	.0005	1.836	.0012	0.471	.0022	5.089	12
49	.0001	1.16	.0005	1.544	.0012	0.35	.0022	5.023	11
50	1.0001	68.757	1.0005	31.257	1.0012	20.23	1.0022	14.958	10
51	.0001	7.409	.0005	30.976	.0012	0.112	.0023	4.893	9
52	.0001	6.113	.0005	0.699	.0012	19.995	.0023	4.829	8
53	.0001	4.866	.0005	0.428	.0013	9.88	.0023	4.765	7
54	.0001	3.664	.0005	0.161	.0013	9.766	.0023	4.702	6
55	1.0001	62.507	1.0005	29.899	1.0013	19.653	1.0023	14.64	5
56	.0001	1.391	.0006	9.641	.0013	9.541	.0024	4.578	4
57	.0001	1.314	.0006	9.388	.0013	9.431	.0024	4.517	3
58	.0001	59.274	.0006	9.139	.0013	9.322	.0024	4.456	2
59	.0001	8.27	.0006	8.894	.0013	9.214	.0024	4.395	1
60	1.0001	57.299	1.0006	28.654	1.0014	19.107	1.0024	14.335	0
	Co-sec't.	SECANT.	Co-sec't.	SECANT.	Co-sec't.	SECANT.	Co-sec't.	SECANT.	
	89°		88°		87°		86°		

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NATURAL SECANTS AND CO-SECANTS.

	40°		50°		60°		70°		
'	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	'
0	1.0024	14.335	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	60
1	.0025	4.276	.0038	1.436	.0055	.5404	.0075	.1861	59
2	.0025	4.217	.0039	1.398	.0056	.5141	.0076	.1668	58
3	.0025	4.159	.0039	1.36	.0056	.488	.0076	.1476	57
4	.0025	4.101	.0039	1.323	.0056	.462	.0076	.1285	56
5	1.0025	14.043	1.0039	11.286	1.0057	9.4362	1.0077	8.1094	55
6	.0026	3.986	.004	1.249	.0057	.4105	.0077	.0905	54
7	.0026	3.93	.004	1.213	.0057	.385	.0078	.0717	53
8	.0026	3.874	.004	1.176	.0057	.3596	.0078	.0529	52
9	.0026	3.818	.004	1.14	.0058	.3343	.0078	.0342	51
10	1.0026	13.763	1.0041	11.104	1.0058	9.3092	1.0079	8.0156	50
11	.0027	3.708	.0041	1.069	.0058	.2842	.0079	7.9971	49
12	.0027	3.654	.0041	1.033	.0059	.2593	.0079	.9787	48
13	.0027	3.6	.0041	0.988	.0059	.2346	.008	.9604	47
14	.0027	3.547	.0042	0.963	.0059	.21	.008	.9421	46
15	1.0027	13.494	1.0042	10.929	1.006	9.1855	1.008	7.924	45
16	.0028	3.441	.0042	0.894	.006	.1612	.0081	.9059	44
17	.0028	3.389	.0043	0.86	.006	.137	.0081	.8879	43
18	.0028	3.337	.0043	0.826	.0061	.1129	.0082	.87	42
19	.0028	3.286	.0043	0.792	.0061	.089	.0082	.8522	41
20	1.0029	13.235	1.0043	10.758	1.0061	9.0651	1.0082	7.8344	40
21	.0029	3.184	.0044	0.725	.0062	.0414	.0083	.8168	39
22	.0029	3.134	.0044	0.692	.0062	.0179	.0083	.7992	38
23	.0029	3.084	.0044	0.659	.0062	8.9944	.0084	.7817	37
24	.0029	3.034	.0044	0.626	.0063	.9711	.0084	.7642	36
25	1.003	12.985	1.0045	10.593	1.0063	8.9479	1.0084	7.7469	35
26	.003	2.937	.0045	0.561	.0063	.9248	.0085	.7296	34
27	.003	2.888	.0045	0.529	.0064	.9018	.0085	.7124	33
28	.003	2.84	.0046	0.497	.0064	.879	.0085	.6953	32
29	.0031	2.793	.0046	0.465	.0064	.8563	.0086	.6783	31
30	1.0031	12.745	1.0046	10.433	1.0065	8.8337	1.0086	7.6613	30
31	.0031	2.698	.0046	0.402	.0065	.8112	.0087	.6444	29
32	.0031	2.652	.0047	0.371	.0065	.7888	.0087	.6276	28
33	.0032	2.606	.0047	0.34	.0066	.7665	.0087	.6108	27
34	.0032	2.56	.0047	0.309	.0066	.7444	.0088	.5942	26
35	1.0032	12.514	1.0048	10.278	1.0066	8.7223	1.0088	7.5776	25
36	.0032	2.469	.0048	0.248	.0067	.7004	.0089	.5611	24
37	.0032	2.424	.0048	0.217	.0067	.6786	.0089	.5446	23
38	.0033	2.379	.0048	0.187	.0067	.6569	.0089	.5282	22
39	.0033	2.335	.0049	0.157	.0068	.6353	.009	.5119	21
40	1.0033	12.291	1.0049	10.127	1.0068	8.6138	1.009	7.4957	20
41	.0033	2.248	.0049	0.098	.0068	.5924	.009	.4795	19
42	.0034	2.204	.005	0.068	.0069	.5711	.0091	.4634	18
43	.0034	2.161	.005	0.039	.0069	.5499	.0091	.4474	17
44	.0034	2.118	.005	0.01	.0069	.5289	.0092	.4315	16
45	1.0034	12.076	1.005	9.9812	1.007	8.5079	1.0092	7.4156	15
46	.0035	2.034	.0051	.9525	.007	.4871	.0092	.3998	14
47	.0035	1.992	.0051	.9239	.007	.4663	.0093	.384	13
48	.0035	1.95	.0051	.8955	.0071	.4457	.0093	.3683	12
49	.0035	1.909	.0052	.8672	.0071	.4251	.0094	.3527	11
50	1.0036	11.868	1.0052	9.8391	1.0071	8.4046	1.0094	7.3372	10
51	.0036	1.828	.0052	.8112	.0072	.3843	.0094	.3217	9
52	.0036	1.787	.0053	.7834	.0072	.3640	.0095	.3063	8
53	.0036	1.747	.0053	.7558	.0073	.3439	.0095	.2909	7
54	.0037	1.707	.0053	.7283	.0073	.3238	.0096	.2757	6
55	1.0037	11.668	1.0053	9.701	1.0073	8.3039	1.0096	7.2604	5
56	.0037	1.628	.0054	.6739	.0074	.2840	.0097	.2453	4
57	.0037	1.589	.0054	.6469	.0074	.2642	.0097	.2302	3
58	.0038	1.55	.0054	.62	.0074	.2446	.0097	.2152	2
59	.0038	1.512	.0055	.5933	.0075	.225	.0098	.2002	1
60	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	.0098	7.1853	0
'	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	'
	85°		84°		83°		82°		

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NATURAL SECANTS AND CO-SECANTS.

°	8°		9°		10°		11°		°
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.0098	7.1853	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	60
1	.0099	.1704	.0125	.3807	.0155	.7493	.0188	.233	59
2	.0099	.1557	.0125	.369	.0155	.7398	.0188	.2252	58
3	.0099	.1409	.0126	.3574	.0156	.7304	.0189	.2174	57
4	.01	.1263	.0126	.3458	.0156	.721	.0189	.2097	56
5	1.01	7.1117	1.0127	6.3343	1.0157	5.7117	1.019	5.2019	55
6	.0101	.0972	.0127	.3228	.0157	.7023	.0191	.1942	54
7	.0101	.0827	.0128	.3113	.0158	.693	.0191	.1865	53
8	.0102	.0683	.0128	.2999	.0158	.6838	.0192	.1788	52
9	.0102	.0539	.0129	.2885	.0159	.6745	.0192	.1712	51
10	1.0102	7.0396	1.0129	6.2772	1.0159	5.6653	1.0193	5.1636	50
11	.0103	.0524	.013	.2659	.016	.6561	.0193	.156	49
12	.0103	.0412	.013	.2546	.016	.647	.0194	.1484	48
13	.0104	6.9971	.0131	.2434	.0161	.6379	.0195	.1409	47
14	.0104	.983	.0131	.2322	.0162	.6288	.0195	.1333	46
15	1.0104	6.969	1.0132	6.2211	1.0162	5.6197	1.0196	5.1258	45
16	.0105	.955	.0132	.21	.0163	.6107	.0196	.1183	44
17	.0105	.9411	.0133	.199	.0163	.6017	.0197	.1109	43
18	.0106	.9273	.0133	.188	.0164	.5928	.0198	.1034	42
19	.0106	.9135	.0134	.177	.0164	.5838	.0198	.096	41
20	1.0107	6.8998	1.0134	6.1661	1.0165	5.5749	1.0199	5.0886	40
21	.0107	.8861	.0135	.1552	.0165	.566	.0199	.0812	39
22	.0107	.8725	.0135	.1443	.0166	.5572	.02	.0739	38
23	.0108	.8589	.0136	.1335	.0166	.5484	.0201	.0666	37
24	.0108	.8454	.0136	.1227	.0167	.5396	.0201	.0593	36
25	1.0109	6.832	1.0136	6.112	1.0167	5.5308	1.0202	5.052	35
26	.0109	.8185	.0137	.1013	.0168	.5221	.0202	.0447	34
27	.011	.8052	.0137	.0906	.0169	.5134	.0203	.0375	33
28	.011	.7919	.0138	.08	.0169	.5047	.0204	.0302	32
29	.0111	.7787	.0138	.0694	.017	.496	.0204	.023	31
30	1.0111	6.7655	1.0139	6.0588	1.017	5.4874	1.0205	5.0158	30
31	.0111	.7523	.0139	.0483	.0171	.4788	.0205	.0087	29
32	.0112	.7392	.014	.0379	.0171	.4702	.0206	.0015	28
33	.0112	.7262	.014	.0274	.0172	.4617	.0207	4.9944	27
34	.0113	.7132	.0141	.017	.0172	.4532	.0207	.9873	26
35	1.0113	6.7003	1.0141	6.0066	1.0173	5.4447	1.0208	4.9802	25
36	.0114	.6874	.0142	5.9963	.0174	.4362	.0208	.9732	24
37	.0114	.6745	.0142	.986	.0174	.4278	.0209	.9661	23
38	.0115	.6617	.0143	.9758	.0175	.4194	.021	.9591	22
39	.0115	.649	.0143	.9655	.0175	.411	.021	.9521	21
40	1.0115	6.6363	1.0144	5.9554	1.0176	5.4026	1.0211	4.9452	20
41	.0116	.6237	.0144	.9452	.0176	.3943	.0211	.9382	19
42	.0116	.6111	.0145	.9351	.0177	.386	.0212	.9313	18
43	.0117	.5985	.0145	.925	.0177	.3777	.0213	.9243	17
44	.0117	.586	.0146	.915	.0178	.3695	.0213	.9175	16
45	1.0118	6.5736	1.0146	5.9049	1.0179	5.3612	1.0214	4.9106	15
46	.0118	.5612	.0147	.895	.0179	.353	.0215	.9037	14
47	.0119	.5488	.0147	.885	.018	.3449	.0215	.8969	13
48	.0119	.5365	.0148	.8751	.018	.3367	.0216	.8901	12
49	.0119	.5243	.0148	.8652	.0181	.3286	.0216	.8833	11
50	1.012	6.5121	1.0149	5.8554	1.0181	5.3205	1.0217	4.8765	10
51	.012	.4999	.015	.8456	.0182	.3124	.0218	.8697	9
52	.0121	.4878	.015	.8358	.0182	.3044	.0218	.863	8
53	.0121	.4757	.0151	.8261	.0183	.2963	.0219	.8563	7
54	.0122	.4637	.0151	.8163	.0184	.2883	.022	.8496	6
55	1.0122	6.4517	1.0152	5.8067	1.0184	5.2803	1.022	4.8429	5
56	.0123	.4398	.0152	.797	.0185	.2724	.0221	.8362	4
57	.0123	.4279	.0153	.7874	.0185	.2645	.0221	.8296	3
58	.0124	.416	.0153	.7778	.0186	.2566	.0222	.8229	2
59	.0124	.4042	.0154	.7683	.0186	.2487	.0223	.8163	1
60	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	1.0223	4.8097	0
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	
	81°		80°		79°		78°		

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NATURAL SECANTS AND CO-SECANTS.

	12°		13°		14°		15°		
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.0223	4.8097	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	60
1	.0224	.8032	.0264	.4398	.0307	.1287	.0353	.8595	59
2	.0225	.7966	.0264	.4342	.0308	.1239	.0354	.8553	58
3	.0225	.7901	.0265	.4287	.0308	.1191	.0355	.8512	57
4	.0226	.7835	.0266	.4231	.0309	.1144	.0356	.847	56
5	1.0226	4.777	1.0266	4.4176	1.031	4.1096	1.0357	3.8428	55
6	.0227	.7706	.0267	.4121	.0311	.1048	.0358	.8387	54
7	.0228	.7641	.0268	.4065	.0311	.1001	.0358	.8346	53
8	.0228	.7576	.0268	.4011	.0312	.0953	.0359	.8304	52
9	.0229	.7512	.0269	.3956	.0313	.0906	.036	.8263	51
10	1.023	4.7448	1.027	4.3901	1.0314	4.0859	1.0361	3.8222	50
11	.023	.7384	.0271	.3847	.0314	.0812	.0362	.8181	49
12	.0231	.732	.0271	.3792	.0315	.0765	.0362	.814	48
13	.0232	.7257	.0272	.3738	.0316	.0718	.0363	.81	47
14	.0232	.7193	.0273	.3684	.0317	.0672	.0364	.8059	46
15	1.0233	4.713	1.0273	4.363	1.0317	4.0625	1.0365	3.8018	45
16	.0234	.7067	.0274	.3576	.0318	.0579	.0366	.7978	44
17	.0234	.7004	.0275	.3522	.0319	.0532	.0367	.7937	43
18	.0235	.6942	.0276	.3469	.032	.0486	.0367	.7897	42
19	.0235	.6879	.0276	.3415	.032	.044	.0368	.7857	41
20	1.0236	4.6817	1.0277	4.3362	1.0321	4.0394	1.0369	3.7816	40
21	.0237	.6754	.0278	.3309	.0322	.0348	.037	.7776	39
22	.0237	.6692	.0278	.3256	.0323	.0302	.0371	.7736	38
23	.0238	.6631	.0279	.3203	.0323	.0256	.0371	.7697	37
24	.0239	.6569	.028	.315	.0324	.0211	.0372	.7657	36
25	1.0239	4.6507	1.028	4.3098	1.0325	4.0165	1.0373	3.7617	35
26	.024	.6446	.0281	.3045	.0326	.012	.0374	.7577	34
27	.0241	.6385	.0282	.2993	.0327	.0074	.0375	.7538	33
28	.0241	.6324	.0283	.2941	.0327	.0029	.0376	.7498	32
29	.0242	.6263	.0283	.2888	.0328	3.9984	.0376	.7459	31
30	1.0243	4.6202	1.0284	4.2836	1.0329	3.9939	1.0377	3.742	30
31	.0243	.6142	.0285	.2785	.033	.9894	.0378	.738	29
32	.0244	.6081	.0285	.2733	.033	.985	.0379	.7341	28
33	.0245	.6021	.0286	.2681	.0331	.9805	.038	.7302	27
34	.0245	.5961	.0287	.263	.0332	.976	.0381	.7263	26
35	1.0246	4.5901	1.0288	4.2579	1.0333	3.9716	1.0382	3.7224	25
36	.0247	.5841	.0288	.2527	.0334	.9672	.0382	.7186	24
37	.0247	.5782	.0289	.2476	.0334	.9627	.0383	.7147	23
38	.0248	.5722	.029	.2425	.0335	.9583	.0384	.7108	22
39	.0249	.5663	.0291	.2375	.0336	.9539	.0385	.707	21
40	1.0249	4.5604	1.0291	4.2324	1.0337	3.9495	1.0386	3.7031	20
41	.025	.5545	.0292	.2273	.0338	.9451	.0387	.6993	19
42	.0251	.5486	.0293	.2223	.0338	.9408	.0387	.6955	18
43	.0251	.5428	.0293	.2173	.0339	.9364	.0388	.6917	17
44	.0252	.5369	.0294	.2122	.034	.932	.0389	.6878	16
45	1.0253	4.5311	1.0295	4.2072	1.0341	3.9277	1.039	3.684	15
46	.0253	.5253	.0296	.2022	.0341	.9234	.0391	.6802	14
47	.0254	.5195	.0296	.1972	.0342	.919	.0392	.6765	13
48	.0255	.5137	.0297	.1923	.0343	.9147	.0393	.6727	12
49	.0255	.5079	.0298	.1873	.0344	.9104	.0393	.6689	11
50	1.0256	4.5021	1.0299	4.1824	1.0345	3.9061	1.0394	3.6651	10
51	.0257	.4964	.0299	.1774	.0345	.9018	.0395	.6614	9
52	.0257	.4907	.03	.1725	.0346	.8976	.0396	.6576	8
53	.0258	.485	.0301	.1676	.0347	.8933	.0397	.6539	7
54	.0259	.4793	.0302	.1627	.0348	.889	.0398	.6502	6
55	1.026	4.4736	1.0302	4.1578	1.0349	3.8848	1.0399	3.6464	5
56	.026	.4679	.0303	.1529	.0349	.8805	.0399	.6427	4
57	.0261	.4623	.0304	.1481	.035	.8763	.04	.639	3
58	.0262	.4566	.0305	.1432	.0351	.8721	.0401	.6353	2
59	.0262	.451	.0305	.1384	.0352	.8679	.0402	.6316	1
60	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	1.0403	3.6279	0
	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	
	77°		76°		75°		74°		

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NATURAL SECANTS AND CO-SECANTS.

	16°		17°		18°		19°		
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.0403	3.6279	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	60
1	.0404	.6243	.0458	.417	.0516	.2332	.0577	.069	59
2	.0405	.6206	.0459	.4138	.0517	.2303	.0578	.0664	58
3	.0406	.6169	.046	.4106	.0518	.2274	.0579	.0638	57
4	.0406	.6133	.0461	.4073	.0519	.2245	.058	.0612	56
5	1.0407	3.6096	1.0461	3.4041	1.052	3.2216	1.0581	3.0586	55
6	.0408	.606	.0462	.4009	.0521	.2188	.0582	.0561	54
7	.0409	.6024	.0463	.3977	.0522	.2159	.0584	.0535	53
8	.041	.5987	.0464	.3945	.0523	.2131	.0585	.0509	52
9	.0411	.5951	.0465	.3913	.0524	.2102	.0586	.0484	51
10	1.0412	3.5915	1.0466	3.3881	1.0525	3.2074	1.0587	3.0458	50
11	.0413	.5879	.0467	.3849	.0526	.2045	.0588	.0433	49
12	.0413	.5843	.0468	.3817	.0527	.2017	.0589	.0407	48
13	.0414	.5807	.0469	.3785	.0528	.1989	.059	.0382	47
14	.0415	.5772	.047	.3754	.0529	.196	.0591	.0357	46
15	1.0416	3.5736	1.0471	3.3722	1.053	3.1932	1.0592	3.0331	45
16	.0417	.57	.0472	.369	.0531	.1904	.0593	.0306	44
17	.0418	.5665	.0473	.3659	.0532	.1876	.0594	.0281	43
18	.0419	.5629	.0474	.3627	.0533	.1848	.0595	.0256	42
19	.042	.5594	.0475	.3596	.0534	.182	.0596	.0231	41
20	1.042	3.5559	1.0476	3.3565	1.0535	3.1792	1.0598	3.0206	40
21	.0421	.5523	.0477	.3534	.0536	.1764	.0599	.0181	39
22	.0422	.5488	.0478	.3502	.0537	.1736	.06	.0156	38
23	.0423	.5453	.0478	.3471	.0538	.1708	.0601	.0131	37
24	.0424	.5418	.0479	.344	.0539	.1681	.0602	.0106	36
25	1.0425	3.5383	1.048	3.3409	1.054	3.1653	1.0603	3.0081	35
26	.0426	.5348	.0481	.3378	.0541	.1625	.0604	.0056	34
27	.0427	.5313	.0482	.3347	.0542	.1598	.0605	.0031	33
28	.0428	.5279	.0483	.3316	.0543	.157	.0606	.0007	32
29	.0428	.5244	.0484	.3286	.0544	.1543	.0607	.29982	31
30	1.0429	3.5209	1.0485	3.3255	1.0545	3.1515	1.0608	2.9957	30
31	.043	.5175	.0486	.3224	.0546	.1488	.0609	.9933	29
32	.0431	.514	.0487	.3194	.0547	.1461	.0611	.9908	28
33	.0432	.5106	.0488	.3163	.0548	.1433	.0612	.9884	27
34	.0433	.5072	.0489	.3133	.0549	.1406	.0613	.9859	26
35	1.0434	3.5037	1.049	3.3102	1.055	3.1379	1.0614	2.9835	25
36	.0435	.5003	.0491	.3072	.0551	.1352	.0615	.981	24
37	.0436	.4969	.0492	.3042	.0552	.1325	.0616	.9786	23
38	.0437	.4935	.0493	.3011	.0553	.1298	.0617	.9762	22
39	.0438	.4901	.0494	.2981	.0554	.1271	.0618	.9738	21
40	1.0438	3.4867	1.0495	3.2951	1.0555	3.1244	1.0619	2.9713	20
41	.0439	.4833	.0496	.2921	.0556	.1217	.062	.9689	19
42	.044	.4799	.0497	.2891	.0557	.119	.0622	.9665	18
43	.0441	.4766	.0498	.2861	.0558	.1163	.0623	.9641	17
44	.0442	.4732	.0499	.2831	.0559	.1137	.0624	.9617	16
45	1.0443	3.4698	1.05	3.2801	1.056	3.111	1.0625	2.9593	15
46	.0444	.4665	.0501	.2772	.0561	.1083	.0626	.9569	14
47	.0445	.4632	.0502	.2742	.0562	.1057	.0627	.9545	13
48	.0446	.4598	.0503	.2712	.0563	.103	.0628	.9521	12
49	.0447	.4565	.0504	.2683	.0565	.1004	.0629	.9497	11
50	1.0448	3.4532	1.0505	3.2653	1.0566	3.0977	1.063	2.9474	10
51	.0448	.4498	.0506	.2624	.0567	.0951	.0632	.945	9
52	.0449	.4465	.0507	.2594	.0568	.0925	.0633	.9426	8
53	.045	.4432	.0508	.2565	.0569	.0898	.0634	.9402	7
54	.0451	.4399	.0509	.2535	.057	.0872	.0635	.9379	6
55	1.0452	3.4366	1.051	3.2506	1.0571	3.0846	1.0636	2.9355	5
56	.0453	.4334	.0511	.2477	.0572	.082	.0637	.9332	4
57	.0454	.4301	.0512	.2448	.0573	.0793	.0638	.9308	3
58	.0455	.4268	.0513	.2419	.0574	.0767	.0639	.9285	2
59	.0456	.4236	.0514	.239	.0575	.0741	.0641	.9261	1
60	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	1.0642	2.9238	0
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	
	73°		72°		71°		70°		

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NATURAL SECANTS AND CO-SECANTS.

	20°		21°		22°		23°		
	SECANT.	CO-SEC'T	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.0642	2.9238	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	60
1	.0643	.9215	.0713	.7883	.0787	.6675	.0865	.5575	59
2	.0644	.9191	.0714	.7862	.0788	.6656	.0866	.5558	58
3	.0645	.9168	.0715	.7841	.0789	.6637	.0868	.554	57
4	.0646	.9145	.0716	.782	.079	.6618	.0869	.5523	56
5	1.0647	2.9122	1.0717	2.7799	1.0792	2.6599	1.087	2.5506	55
6	.0648	.9098	.0719	.7778	.0793	.658	.0872	.5488	54
7	.065	.9075	.072	.7757	.0794	.6561	.0873	.5471	53
8	.0651	.9052	.0721	.7736	.0795	.6542	.0874	.5453	52
9	.0652	.9029	.0722	.7715	.0797	.6523	.0876	.5436	51
10	1.0653	2.9006	1.0723	2.7694	1.0798	2.6504	1.0877	2.5419	50
11	.0654	.8983	.0725	.7674	.0799	.6485	.0878	.5402	49
12	.0655	.896	.0726	.7653	.0801	.6466	.088	.5384	48
13	.0656	.8937	.0727	.7632	.0802	.6447	.0881	.5367	47
14	.0658	.8915	.0728	.7611	.0803	.6428	.0882	.535	46
15	1.0659	2.8892	1.0729	2.7591	1.0804	2.641	1.0884	2.5333	45
16	.066	.8869	.0731	.757	.0806	.6391	.0885	.5316	44
17	.0661	.8846	.0732	.755	.0807	.6372	.0886	.5299	43
18	.0662	.8824	.0733	.7529	.0808	.6353	.0888	.5281	42
19	.0663	.8801	.0734	.7509	.081	.6335	.0889	.5264	41
20	1.0664	2.8778	1.0736	2.7488	1.0811	2.6316	1.0891	2.5247	40
21	.0666	.8756	.0737	.7468	.0812	.6297	.0892	.523	39
22	.0667	.8733	.0738	.7447	.0813	.6279	.0893	.5213	38
23	.0668	.8711	.0739	.7427	.0815	.626	.0895	.5196	37
24	.0669	.8688	.074	.7406	.0816	.6242	.0896	.5179	36
25	1.067	2.8666	1.0742	2.7386	1.0817	2.6223	1.0897	2.5163	35
26	.0671	.8644	.0743	.7366	.0819	.6205	.0899	.5146	34
27	.0673	.8621	.0744	.7346	.082	.6186	.09	.5129	33
28	.0674	.8599	.0745	.7325	.0821	.6168	.0902	.5112	32
29	.0675	.8577	.0747	.7305	.0823	.615	.0903	.5095	31
30	1.0676	2.8554	1.0748	2.7285	1.0824	2.6131	1.0904	2.5078	30
31	.0677	.8532	.0749	.7265	.0825	.6113	.0906	.5062	29
32	.0678	.851	.075	.7245	.0826	.6095	.0907	.5045	28
33	.0679	.8488	.0751	.7225	.0828	.6076	.0908	.5028	27
34	.0681	.8466	.0753	.7205	.0829	.6058	.091	.5011	26
35	1.0682	2.8444	1.0754	2.7185	1.083	2.604	1.0911	2.4995	25
36	.0683	.8422	.0755	.7165	.0832	.6022	.0913	.4978	24
37	.0684	.84	.0756	.7145	.0833	.6003	.0914	.4961	23
38	.0685	.8378	.0758	.7125	.0834	.5985	.0915	.4945	22
39	.0686	.8356	.0759	.7105	.0836	.5967	.0917	.4928	21
40	1.0688	2.8334	1.076	2.7085	1.0837	2.5949	1.0918	2.4912	20
41	.0689	.8312	.0761	.7065	.0838	.5931	.092	.4895	19
42	.069	.829	.0763	.7045	.084	.5913	.0921	.4879	18
43	.0691	.8269	.0764	.7026	.0841	.5895	.0922	.4862	17
44	.0692	.8247	.0765	.7006	.0842	.5877	.0924	.4846	16
45	1.0694	2.8225	1.0766	2.6986	1.0844	2.5859	1.0925	2.4829	15
46	.0695	.8204	.0768	.6967	.0845	.5841	.0927	.4813	14
47	.0696	.8182	.0769	.6947	.0846	.5823	.0928	.4797	13
48	.0697	.816	.077	.6927	.0847	.5805	.0929	.478	12
49	.0698	.8139	.0771	.6908	.0849	.5787	.0931	.4764	11
50	1.0699	2.8117	1.0773	2.6888	1.085	2.577	1.0932	2.4748	10
51	.0701	.8096	.0774	.6869	.0851	.5752	.0934	.4731	9
52	.0702	.8074	.0775	.6849	.0853	.5734	.0935	.4715	8
53	.0703	.8053	.0776	.683	.0854	.5716	.0936	.4699	7
54	.0704	.8032	.0778	.681	.0855	.5699	.0938	.4683	6
55	1.0705	2.801	1.0779	2.6791	1.0857	2.5681	1.0939	2.4666	5
56	.0707	.7989	.078	.6772	.0858	.5663	.0941	.465	4
57	.0708	.7968	.0781	.6752	.0859	.5646	.0942	.4634	3
58	.0709	.7947	.0783	.6733	.0861	.5628	.0943	.4618	2
59	.071	.7925	.0784	.6714	.0862	.561	.0945	.4602	1
60	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	.0946	2.4586	0
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	
	69°		68°		67°		66°		

NATURAL SECANTS AND CO-SECANTS.

°	24°		25°		26°		27°		°
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.0946	2.4586	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	60
1	.0948	.457	.1035	.3647	.1127	.2798	.1225	.2014	59
2	.0949	.4554	.1037	.3632	.1129	.2784	.1226	.2002	58
3	.0951	.4538	.1038	.3618	.1131	.2771	.1228	.1989	57
4	.0952	.4522	.104	.3603	.1132	.2757	.123	.1977	56
5	1.0953	2.4506	1.1041	2.3588	1.1134	2.2744	1.1231	2.1964	55
6	.0955	.449	.1043	.3574	.1135	.273	.1233	.1952	54
7	.0956	.4474	.1044	.3559	.1137	.2717	.1235	.1939	53
8	.0958	.4458	.1046	.3544	.1139	.2703	.1237	.1927	52
9	.0959	.4442	.1047	.353	.114	.269	.1238	.1914	51
10	1.0961	2.4426	1.1049	2.3515	1.1142	2.2676	1.124	2.1902	50
11	.0962	.4411	.105	.3501	.1143	.2663	.1242	.1889	49
12	.0963	.4395	.1052	.3486	.1145	.265	.1243	.1877	48
13	.0965	.4379	.1053	.3472	.1147	.2636	.1245	.1865	47
14	.0966	.4363	.1055	.3457	.1148	.2623	.1247	.1852	46
15	1.0968	2.4347	1.1056	2.3443	1.115	2.261	1.1248	2.184	45
16	.0969	.4332	.1058	.3428	.1151	.2596	.125	.1828	44
17	.0971	.4316	.1059	.3414	.1153	.2583	.1252	.1815	43
18	.0972	.43	.1061	.3399	.1155	.257	.1253	.1803	42
19	.0973	.4285	.1062	.3385	.1156	.2556	.1255	.1791	41
20	1.0975	2.4269	1.1064	2.3371	1.1158	2.2543	1.1257	2.1778	40
21	.0976	.4254	.1065	.3356	.1159	.253	.1258	.1766	39
22	.0978	.4238	.1067	.3342	.1161	.2517	.126	.1754	38
23	.0979	.4222	.1068	.3328	.1163	.2503	.1262	.1742	37
24	.0981	.4207	.107	.3313	.1164	.249	.1264	.173	36
25	1.0982	2.4191	1.1072	2.3299	1.1166	2.2477	1.1265	2.1717	35
26	.0984	.4176	.1073	.3285	.1167	.2464	.1267	.1705	34
27	.0985	.416	.1075	.3271	.1169	.2451	.1269	.1693	33
28	.0986	.4145	.1076	.3256	.1171	.2438	.127	.1681	32
29	.0988	.413	.1078	.3242	.1172	.2425	.1272	.1669	31
30	1.0989	2.4114	1.1079	2.3228	1.1174	2.2411	1.1274	2.1657	30
31	.0991	.4099	.1081	.3214	.1176	.2398	.1275	.1645	29
32	.0992	.4083	.1082	.32	.1177	.2385	.1277	.1633	28
33	.0994	.4068	.1084	.3186	.1179	.2372	.1279	.162	27
34	.0995	.4053	.1085	.3172	.118	.2359	.1281	.1608	26
35	1.0997	2.4037	1.1087	2.3158	1.1182	2.2346	1.1282	2.1596	25
36	.0998	.4022	.1088	.3143	.1184	.2333	.1284	.1584	24
37	.1	.4007	.109	.3129	.1185	.232	.1286	.1572	23
38	.1001	.3992	.1092	.3115	.1187	.2307	.1287	.156	22
39	.1003	.3976	.1093	.3101	.1189	.2294	.1289	.1548	21
40	1.1004	2.3961	1.1095	2.3087	1.119	2.2282	1.1291	2.1536	20
41	.1005	.3946	.1096	.3073	.1192	.2269	.1293	.1525	19
42	.1007	.3931	.1098	.3059	.1193	.2256	.1294	.1513	18
43	.1008	.3916	.1099	.3046	.1195	.2243	.1296	.1501	17
44	.101	.3901	.1101	.3032	.1197	.223	.1298	.1489	16
45	1.1011	2.3886	1.1102	2.3018	1.1198	2.2217	1.1299	2.1477	15
46	.1013	.3871	.1104	.3004	.12	.2204	.1301	.1465	14
47	.1014	.3856	.1106	.299	.1202	.2192	.1303	.1453	13
48	.1016	.3841	.1107	.2976	.1203	.2179	.1305	.1441	12
49	.1017	.3826	.1109	.2962	.1205	.2166	.1306	.143	11
50	1.1019	2.3811	1.111	2.2949	1.1207	2.2153	1.1308	2.1418	10
51	.102	.3796	.1112	.2935	.1208	.2141	.131	.1406	9
52	.1022	.3781	.1113	.2921	.121	.2128	.1312	.1394	8
53	.1023	.3766	.1115	.2907	.1212	.2115	.1313	.1382	7
54	.1025	.3751	.1116	.2894	.1213	.2103	.1315	.1371	6
55	1.1026	2.3736	1.1118	2.288	1.1215	2.209	1.1317	2.1359	5
56	.1028	.3721	.112	.2866	.1217	.2077	.1319	.1347	4
57	.1029	.3706	.1121	.2853	.1218	.2065	.132	.1335	3
58	.1031	.3691	.1123	.2839	.122	.2052	.1322	.1324	2
59	.1032	.3677	.1124	.2825	.1222	.2039	.1324	.1312	1
60	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	1.1326	2.13	0
°	65°		64°		63°		62°		°
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	

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NATURAL SECANTS AND CO-SECANTS.

	28°		29°		30°		31°		
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.1326	2.13	1.1433	2.0627	1.1547	2	1.1666	1.9416	60
1	.1327	.1289	.1435	.0616	.1549	1.999	.1668	.9407	59
2	.1329	.1277	.1437	.0605	.1551	.998	.167	.9397	58
3	.1331	.1266	.1439	.0594	.1553	.997	.1672	.9388	57
4	.1333	.1254	.1441	.0583	.1555	.996	.1674	.9378	56
5	1.1334	2.1242	1.1443	2.0573	1.1557	1.995	1.1676	1.9369	55
6	.1336	.1231	.1445	.0562	.1559	.994	.1678	.936	54
7	.1338	.1219	.1446	.0551	.1561	.993	.1681	.935	53
8	.134	.1208	.1448	.054	.1562	.992	.1683	.9341	52
9	.1341	.1196	.145	.053	.1564	.991	.1685	.9332	51
10	1.1343	2.1185	1.1452	2.0519	1.1566	1.99	1.1687	1.9322	50
11	.1345	.1173	.1454	.0508	.1568	.989	.1689	.9313	49
12	.1347	.1162	.1456	.0498	.157	.988	.1691	.9304	48
13	.1349	.115	.1458	.0487	.1572	.987	.1693	.9295	47
14	.135	.1139	.1459	.0476	.1574	.986	.1695	.9285	46
15	1.1352	2.1127	1.1461	2.0466	1.1576	1.985	1.1697	1.9276	45
16	.1354	.1116	.1463	.0455	.1578	.984	.1699	.9267	44
17	.1356	.1104	.1465	.0444	.158	.983	.1701	.9258	43
18	.1357	.1093	.1467	.0434	.1582	.982	.1703	.9248	42
19	.1359	.1082	.1469	.0423	.1584	.9811	.1705	.9239	41
20	1.1361	2.107	1.1471	2.0413	1.1586	1.9801	1.1707	1.923	40
21	.1363	.1059	.1473	.0402	.1588	.9791	.1709	.9221	39
22	.1365	.1048	.1474	.0392	.159	.9781	.1712	.9212	38
23	.1366	.1036	.1476	.0381	.1592	.9771	.1714	.9203	37
24	.1368	.1025	.1478	.037	.1594	.9761	.1716	.9193	36
25	1.137	2.1014	1.148	2.036	1.1596	1.9752	1.1718	1.9184	35
26	.1372	.1002	.1482	.0349	.1598	.9742	.172	.9175	34
27	.1373	.0991	.1484	.0339	.16	.9732	.1722	.9166	33
28	.1375	.098	.1486	.0329	.1602	.9722	.1724	.9157	32
29	.1377	.0969	.1488	.0318	.1604	.9713	.1726	.9148	31
30	1.1379	2.0957	1.1489	2.0308	1.1606	1.9703	1.1728	1.9139	30
31	.1381	.0946	.1491	.0297	.1608	.9693	.173	.913	29
32	.1382	.0935	.1493	.0287	.161	.9683	.1732	.9121	28
33	.1384	.0924	.1495	.0276	.1612	.9674	.1734	.9112	27
34	.1386	.0912	.1497	.0266	.1614	.9664	.1737	.9102	26
35	1.1388	2.0901	1.1499	2.0256	1.1616	1.9654	1.1739	1.9093	25
36	.139	.089	.1501	.0245	.1618	.9645	.1741	.9084	24
37	.1391	.0879	.1503	.0235	.162	.9635	.1743	.9075	23
38	.1393	.0868	.1505	.0224	.1622	.9625	.1745	.9066	22
39	.1395	.0857	.1507	.0214	.1624	.9616	.1747	.9057	21
40	1.1397	2.0846	1.1508	2.0204	1.1626	1.9606	1.1749	1.9048	20
41	.1399	.0835	.151	.0194	.1628	.9596	.1751	.9039	19
42	.1401	.0824	.1512	.0183	.163	.9587	.1753	.903	18
43	.1402	.0812	.1514	.0173	.1632	.9577	.1756	.9021	17
44	.1404	.0801	.1516	.0163	.1634	.9568	.1758	.9013	16
45	1.1406	2.079	1.1518	2.0152	1.1636	1.9558	1.176	1.9004	15
46	.1408	.0779	.152	.0142	.1638	.9549	.1762	.8995	14
47	.141	.0768	.1522	.0132	.164	.9539	.1764	.8986	13
48	.1411	.0757	.1524	.0122	.1642	.953	.1766	.8977	12
49	.1413	.0746	.1526	.0111	.1644	.952	.1768	.8968	11
50	1.1415	2.0735	1.1528	2.0101	1.1646	1.951	1.177	1.8959	10
51	.1417	.0725	.153	.0091	.1648	.9501	.1772	.895	9
52	.1419	.0714	.1531	.0081	.165	.9491	.1775	.8941	8
53	.1421	.0703	.1533	.0071	.1652	.9482	.1777	.8932	7
54	.1422	.0692	.1535	.0061	.1654	.9473	.1779	.8924	6
55	1.1424	2.0681	1.1537	2.005	1.1656	1.9463	1.1781	1.8915	5
56	.1426	.067	.1539	.004	.1658	.9454	.1783	.8906	4
57	.1428	.0659	.1541	.003	.166	.9444	.1785	.8897	3
58	.143	.0648	.1543	.002	.1662	.9435	.1787	.8888	2
59	.1432	.0637	.1545	.001	.1664	.9425	.179	.8879	1
60	1.1433	2.0627	1.1547	2	1.1666	1.9416	1.1792	1.8871	0
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	
	61°		60°		59°		58°		

NATURAL SECANTS AND CO-SECANTS.

°	32°		33°		34°		35°		°
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.1792	1.8871	1.1924	1.8361	1.2062	1.7883	1.2208	1.7434	60
1	.1794	.8862	.1926	.8352	.2064	.7875	.221	.7427	59
2	.1796	.8853	.1928	.8344	.2067	.7867	.2213	.742	58
3	.1798	.8844	.193	.8336	.2069	.786	.2215	.7413	57
4	.18	.8836	.1933	.8328	.2072	.7852	.2218	.7405	56
5	1.1802	1.8827	1.1935	1.832	1.2074	1.7844	1.222	1.7398	55
6	.1805	.8818	.1937	.8311	.2076	.7837	.2223	.7391	54
7	.1807	.8809	.1939	.8303	.2079	.7829	.2225	.7384	53
8	.1809	.8801	.1942	.8295	.2081	.7821	.2228	.7377	52
9	.1811	.8792	.1944	.8287	.2083	.7814	.223	.7369	51
10	1.1813	1.8783	1.1946	1.8279	1.2086	1.7806	1.2233	1.7362	50
11	.1815	.8785	.1948	.8271	.2088	.7798	.2235	.7355	49
12	.1818	.8766	.1951	.8263	.2091	.7791	.2238	.7348	48
13	.182	.8757	.1953	.8255	.2093	.7783	.224	.7341	47
14	.1822	.8749	.1955	.8246	.2095	.7776	.2243	.7334	46
15	1.1824	1.874	1.1958	1.8238	1.2098	1.7768	1.2245	1.7327	45
16	.1826	.8731	.196	.823	.21	.776	.2248	.7319	44
17	.1828	.8723	.1962	.8222	.2103	.7753	.225	.7312	43
18	.1831	.8714	.1964	.8214	.2105	.7745	.2253	.7305	42
19	.1833	.8706	.1967	.8206	.2107	.7738	.2255	.7298	41
20	1.1835	1.8697	1.1969	1.8198	1.211	1.773	1.2258	1.7291	40
21	.1837	.8688	.1971	.819	.2112	.7723	.226	.7284	39
22	.1839	.868	.1974	.8182	.2115	.7715	.2263	.7277	38
23	.1841	.8671	.1976	.8174	.2117	.7708	.2265	.727	37
24	.1844	.8663	.1978	.8166	.2119	.77	.2268	.7263	36
25	1.1846	1.8654	1.198	1.8158	1.2122	1.7693	1.227	1.7256	35
26	.1848	.8646	.1983	.815	.2124	.7685	.2273	.7249	34
27	.185	.8637	.1985	.8142	.2127	.7678	.2276	.7242	33
28	.1852	.8629	.1987	.8134	.2129	.767	.2278	.7234	32
29	.1855	.862	.199	.8126	.2132	.7663	.2281	.7227	31
30	1.1857	1.8611	1.1992	1.8118	1.2134	1.7655	1.2283	1.722	30
31	.1859	.8603	.1994	.811	.2136	.7648	.2286	.7213	29
32	.1861	.8595	.1997	.8102	.2139	.764	.2288	.7206	28
33	.1863	.8586	.1999	.8094	.2141	.7633	.2291	.7199	27
34	.1866	.8578	.2001	.8086	.2144	.7625	.2293	.7192	26
35	1.1868	1.8569	1.2004	1.8078	1.2146	1.7618	1.2296	1.7185	25
36	.187	.8561	.2006	.807	.2149	.761	.2298	.7178	24
37	.1872	.8552	.2008	.8062	.2151	.7603	.2301	.7171	23
38	.1874	.8544	.201	.8054	.2153	.7596	.2304	.7164	22
39	.1877	.8535	.2013	.8047	.2156	.7588	.2306	.7157	21
40	1.1879	1.8527	1.2015	1.8039	1.2158	1.7581	1.2309	1.7151	20
41	.1881	.8519	.2017	.8031	.2161	.7573	.2311	.7144	19
42	.1883	.851	.202	.8023	.2163	.7566	.2314	.7137	18
43	.1886	.8502	.2022	.8015	.2166	.7559	.2316	.713	17
44	.1888	.8493	.2024	.8007	.2168	.7551	.2319	.7123	16
45	1.189	1.8485	1.2027	1.7999	1.2171	1.7544	1.2322	1.7116	15
46	.1892	.8477	.2029	.7992	.2173	.7537	.2324	.7109	14
47	.1894	.8468	.2031	.7984	.2175	.7529	.2327	.7102	13
48	.1897	.846	.2034	.7976	.2178	.7522	.2329	.7095	12
49	.1899	.8452	.2036	.7968	.218	.7514	.2332	.7088	11
50	1.1901	1.8443	1.2039	1.796	1.2183	1.7507	1.2335	1.7081	10
51	.1903	.8435	.2041	.7953	.2185	.75	.2337	.7075	9
52	.1906	.8427	.2043	.7945	.2188	.7493	.234	.7068	8
53	.1908	.8418	.2046	.7937	.219	.7485	.2342	.7061	7
54	.191	.841	.2048	.7929	.2193	.7478	.2345	.7054	6
55	1.1912	1.8402	1.205	1.7921	1.2195	1.7471	1.2348	1.7047	5
56	.1915	.8394	.2053	.7914	.2198	.7463	.235	.704	4
57	.1917	.8385	.2055	.7906	.22	.7456	.2353	.7033	3
58	.1919	.8377	.2057	.7898	.2203	.7449	.2355	.7027	2
59	.1921	.8369	.206	.7891	.2205	.7442	.2358	.702	1
60	1.1922	1.8361	1.2062	1.7883	1.2208	1.7434	1.2361	1.7013	0
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	
	57°		56°		55°		54°		

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NATURAL SECANTS AND CO-SECANTS.

°	36°		37°		38°		39°		°
	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	
0	1.2361	1.7013	1.2521	1.6616	1.269	1.6243	1.2867	1.589	60
1	.2363	.7006	.2524	.661	.2693	.6237	.2871	.5884	59
2	.2366	.6999	.2527	.6603	.2696	.6231	.2874	.5879	58
3	.2368	.6993	.253	.6597	.2699	.6224	.2877	.5873	57
4	.2371	.6986	.2532	.6591	.2702	.6218	.288	.5867	56
5	1.2374	1.6979	1.2535	1.6584	1.2705	1.6212	1.2883	1.5862	55
6	.2376	.6972	.2538	.6578	.2707	.6206	.2886	.5856	54
7	.2379	.6965	.2541	.6572	.271	.62	.2889	.585	53
8	.2382	.6959	.2543	.6565	.2713	.6194	.2892	.5845	52
9	.2384	.6952	.2546	.6559	.2716	.6188	.2895	.5839	51
10	1.2387	1.6945	1.2549	1.6552	1.2719	1.6182	1.2898	1.5833	50
11	.2389	.6938	.2552	.6546	.2722	.6176	.2901	.5828	49
12	.2392	.6932	.2554	.654	.2725	.617	.2904	.5822	48
13	.2395	.6925	.2557	.6533	.2728	.6164	.2907	.5816	47
14	.2397	.6918	.256	.6527	.2731	.6159	.291	.5811	46
15	1.24	1.6912	1.2563	1.6521	1.2734	1.6153	1.2913	1.5805	45
16	.2403	.6905	.2565	.6514	.2737	.6147	.2916	.5799	44
17	.2405	.6898	.2568	.6508	.2739	.6141	.2919	.5794	43
18	.2408	.6891	.2571	.6502	.2742	.6135	.2922	.5788	42
19	.2411	.6885	.2574	.6496	.2745	.6129	.2926	.5783	41
20	1.2413	1.6878	1.2577	1.6489	1.2748	1.6123	1.2929	1.5777	40
21	.2416	.6871	.2579	.6483	.2751	.6117	.2932	.5771	39
22	.2419	.6865	.2582	.6477	.2754	.6111	.2935	.5766	38
23	.2421	.6858	.2585	.647	.2757	.6105	.2938	.576	37
24	.2424	.6851	.2588	.6464	.276	.6099	.2941	.5755	36
25	1.2427	1.6845	1.2591	1.6458	1.2763	1.6093	1.2944	1.5749	35
26	.2429	.6838	.2593	.6452	.2766	.6087	.2947	.5743	34
27	.2432	.6831	.2596	.6445	.2769	.6081	.295	.5738	33
28	.2435	.6825	.2599	.6439	.2772	.6077	.2953	.5732	32
29	.2437	.6818	.2602	.6433	.2775	.607	.2956	.5727	31
30	1.244	1.6812	1.2605	1.6427	1.2778	1.6064	1.296	1.5721	30
31	.2443	.6805	.2607	.642	.2781	.6058	.2963	.5716	29
32	.2445	.6798	.261	.6414	.2784	.6052	.2966	.571	28
33	.2448	.6792	.2613	.6408	.2787	.6046	.2969	.5705	27
34	.2451	.6785	.2616	.6402	.279	.604	.2972	.5699	26
35	1.2453	1.6779	1.2619	1.6396	1.2793	1.6034	1.2975	1.5694	25
36	.2456	.6772	.2622	.6389	.2795	.6029	.2978	.5688	24
37	.2459	.6766	.2624	.6383	.2798	.6023	.2981	.5683	23
38	.2461	.6759	.2627	.6377	.2801	.6017	.2985	.5677	22
39	.2464	.6752	.263	.6371	.2804	.6011	.2988	.5672	21
40	1.2467	1.6746	1.2633	1.6365	1.2807	1.6005	1.2991	1.5666	20
41	.247	.6739	.2636	.6359	.281	.6	.2994	.5661	19
42	.2472	.6733	.2639	.6352	.2813	.5994	.2997	.5655	18
43	.2475	.6726	.2641	.6346	.2816	.5988	.3	.565	17
44	.2473	.672	.2644	.634	.2819	.5982	.3003	.5644	16
45	1.248	1.6713	1.2647	1.6334	1.2822	1.5976	1.3006	1.5639	15
46	.2483	.6707	.265	.6328	.2825	.5971	.301	.5633	14
47	.2486	.67	.2653	.6322	.2828	.5965	.3013	.5628	13
48	.2488	.6694	.2656	.6316	.2831	.5959	.3016	.5622	12
49	.249	.6687	.2659	.6309	.2834	.5953	.3019	.5617	11
50	1.2494	1.6681	1.2661	1.6303	1.2837	1.5947	1.3022	1.5611	10
51	.2497	.6674	.2664	.6297	.284	.5942	.3025	.5606	9
52	.2499	.6668	.2667	.6291	.2843	.5936	.3029	.56	8
53	.2502	.6661	.267	.6285	.2846	.593	.3032	.5595	7
54	.2505	.6655	.2673	.6279	.2849	.5924	.3035	.559	6
55	1.2508	1.6648	1.2676	1.6273	1.2852	1.5919	1.3038	1.5584	5
56	.251	.6642	.2679	.6267	.2855	.5913	.3041	.5579	4
57	.2513	.6636	.2681	.6261	.2858	.5907	.3044	.5573	3
58	.2516	.6629	.2684	.6255	.2861	.5901	.3048	.5568	2
59	.2519	.6623	.2687	.6249	.2864	.5896	.3051	.5563	1
60	1.2521	1.6616	1.269	1.6243	1.2867	1.589	1.3054	1.5557	0
°	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	Co-SEC'T.	SECANT.	°

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NATURAL SECANTS AND CO-SECANTS.

	40°		41°		42°		43°		
	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	
0	1.3054	1.5557	1.325	1.5242	1.3456	1.4945	1.3673	1.4663	60
1	.3057	.5552	.3253	.5237	.346	.494	.3677	.4658	59
2	.306	.5546	.3257	.5232	.3463	.4935	.3681	.4654	58
3	.3064	.5541	.326	.5227	.3467	.493	.3684	.4649	57
4	.3067	.5536	.3263	.5222	.347	.4925	.3688	.4644	56
5	1.307	1.553	1.3267	1.5217	1.3474	1.4921	1.3692	1.464	55
6	.3073	.5525	.327	.5212	.3477	.4916	.3695	.4635	54
7	.3076	.552	.3274	.5207	.3481	.4911	.3699	.4631	53
8	.308	.5514	.3277	.5202	.3485	.4906	.3703	.4626	52
9	.3083	.5509	.328	.5197	.3488	.4901	.3707	.4622	51
10	1.3086	1.5503	1.3284	1.5192	1.3492	1.4897	1.371	1.4617	50
11	.3089	.5498	.3287	.5187	.3495	.4892	.3714	.4613	49
12	.3092	.5493	.329	.5182	.3499	.4887	.3718	.4608	48
13	.3096	.5487	.3294	.5177	.3502	.4882	.3722	.4604	47
14	.3099	.5482	.3297	.5171	.3506	.4877	.3725	.4599	46
15	1.3102	1.5477	1.3301	1.5166	1.3509	1.4873	1.3729	1.4595	45
16	.3105	.5471	.3304	.5161	.3513	.4868	.3733	.459	44
17	.3109	.5466	.3307	.5156	.3517	.4863	.3737	.4586	43
18	.3112	.5461	.3311	.5151	.352	.4858	.374	.4581	42
19	.3115	.5456	.3314	.5146	.3524	.4854	.3744	.4577	41
20	1.3118	1.545	1.3318	1.5141	1.3527	1.4849	1.3748	1.4572	40
21	.3121	.5445	.3321	.5136	.3531	.4844	.3752	.4568	39
22	.3125	.544	.3324	.5131	.3534	.4839	.3756	.4563	38
23	.3128	.5434	.3328	.5126	.3538	.4835	.3759	.4559	37
24	.3131	.5429	.3331	.5121	.3542	.483	.3763	.4554	36
25	1.3134	1.5424	1.3335	1.5116	1.3545	1.4825	1.3767	1.455	35
26	.3138	.5419	.3338	.5111	.3549	.4821	.3771	.4545	34
27	.3141	.5413	.3342	.5106	.3552	.4816	.3774	.4541	33
28	.3144	.5408	.3345	.5101	.3556	.4811	.3778	.4536	32
29	.3148	.5403	.3348	.5096	.356	.4806	.3782	.4532	31
30	1.3151	1.5398	1.3352	1.5092	1.3563	1.4802	1.3786	1.4527	30
31	.3154	.5392	.3355	.5087	.3567	.4797	.379	.4523	29
32	.3157	.5387	.3359	.5082	.3571	.4792	.3794	.4518	28
33	.3161	.5382	.3362	.5077	.3574	.4788	.3797	.4514	27
34	.3164	.5377	.3366	.5072	.3578	.4783	.3801	.451	26
35	1.3167	1.5371	1.3369	1.5067	1.3581	1.4778	1.3805	1.4505	25
36	.317	.5366	.3372	.5062	.3585	.4774	.3809	.4501	24
37	.3174	.5361	.3376	.5057	.3589	.4769	.3813	.4496	23
38	.3177	.5356	.3379	.5052	.3592	.4764	.3816	.4492	22
39	.318	.5351	.3383	.5047	.3596	.476	.382	.4487	21
40	1.3184	1.5345	1.3386	1.5042	1.36	1.4755	1.3824	1.4483	20
41	.3187	.534	.339	.5037	.3603	.475	.3828	.4479	19
42	.319	.5335	.3393	.5032	.3607	.4746	.3832	.4474	18
43	.3193	.533	.3397	.5027	.3611	.4741	.3836	.447	17
44	.3197	.5325	.34	.5022	.3614	.4736	.3839	.4465	16
45	1.32	1.5319	1.3404	1.5018	1.3618	1.4732	1.3843	1.4461	15
46	.3203	.5314	.3407	.5013	.3622	.4727	.3847	.4457	14
47	.3207	.5309	.3411	.5008	.3625	.4723	.3851	.4452	13
48	.321	.5304	.3414	.5003	.3629	.4718	.3855	.4448	12
49	.3213	.5299	.3418	.4998	.3633	.4713	.3859	.4443	11
50	1.3217	1.5294	1.3421	1.4993	1.3636	1.4709	1.3863	1.4439	10
51	.322	.5289	.3425	.4988	.364	.4704	.3867	.4435	9
52	.3223	.5283	.3428	.4983	.3644	.4699	.387	.443	8
53	.3227	.5278	.3432	.4979	.3647	.4695	.3874	.4426	7
54	.323	.5273	.3435	.4974	.3651	.469	.3878	.4422	6
55	1.3233	1.5268	1.3439	1.4969	1.3655	1.4686	1.3882	1.4417	5
56	.3237	.5263	.3442	.4964	.3658	.4681	.3886	.4413	4
57	.324	.5258	.3446	.4959	.3662	.4676	.389	.4408	3
58	.3243	.5253	.3449	.4954	.3666	.4672	.3894	.4404	2
59	.3247	.5248	.3453	.4949	.3669	.4667	.3898	.44	1
60	1.325	1.5242	1.3456	1.4945	1.3673	1.4663	1.3902	1.4395	0
	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	CO-SEC'T.	SECANT.	
	49°		48°		47°		46°		

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NATURAL SECANTS AND CO-SECANTS.

44°				44°				44°			
'	SECANT.	Co-SEC'T.	'	'	SECANT.	Co-SEC'T.	'	'	SECANT.	Co-SEC'T.	'
0	1.3902	1.4395	60	21	1.3984	1.4305	39	41	1.4065	1.4221	19
1	.3905	.4391	59	22	.3988	.4301	38	42	.4069	.4217	18
2	.3909	.4387	58	23	.3992	.4297	37	43	.4073	.4212	17
3	.3913	.4382	57	24	.3996	.4292	36	44	.4077	.4208	16
4	.3917	.4378	56	25	1.4	1.4288	35	45	1.4081	1.4204	15
5	1.3921	1.4374	55	26	.4004	.4284	34	46	.4085	.42	14
6	.3925	.437	54	27	.4008	.428	33	47	.4089	.4196	13
7	.3929	.4365	53	28	.4012	.4276	32	48	.4093	.4192	12
8	.3933	.4361	52	29	.4016	.4271	31	49	.4097	.4188	11
9	.3937	.4357	51	30	1.402	1.4267	30	50	1.4101	1.4183	10
10	1.3941	1.4352	50	31	.4024	.4263	29	51	.4105	.4179	9
11	.3945	.4348	49	32	.4028	.4259	28	52	.4109	.4175	8
12	.3949	.4344	48	33	.4032	.4254	27	53	.4113	.4171	7
13	.3953	.4339	47	34	.4036	.425	26	54	.4117	.4167	6
14	.3957	.4335	46	35	1.404	1.4246	25	55	1.4122	1.4163	5
15	1.396	1.4331	45	36	.4044	.4242	24	56	.4126	.4159	4
16	.3964	.4327	44	37	.4048	.4238	23	57	.413	.4154	3
17	.3968	.4322	43	38	.4052	.4233	22	58	.4134	.415	2
18	.3972	.4318	42	39	.4056	.4229	21	59	.4138	.4146	1
19	.3976	.4314	41	40	1.406	1.4225	20	60	1.4142	1.4142	0
20	1.398	1.431	40								
'	Co-SEC'T.	SECANT.	'	'	Co-SEC'T.	SECANT.	'	'	Co-SEC'T.	SECANT.	'
	45°				45°				45°		

Preceding Table contains Natural Secants and Co-secants for every minute of the Quadrant to Radius 1.

If Degrees are taken at head of column, Minutes, Secant, and Co-secant must be taken from head also; and if they are taken at foot of column, Minutes, etc., must be taken from foot also.

ILLUSTRATION.—1.05 is secant of $17^{\circ} 45'$ and co-secant of $72^{\circ} 15'$.

To Compute Secant or Co-secant of any Angle.

RULE.—Divide 1 by Cosine of angle for Secant, and by Sine for Co-secant.

EXAMPLE 1.—What is secant of $25^{\circ} 25'$?

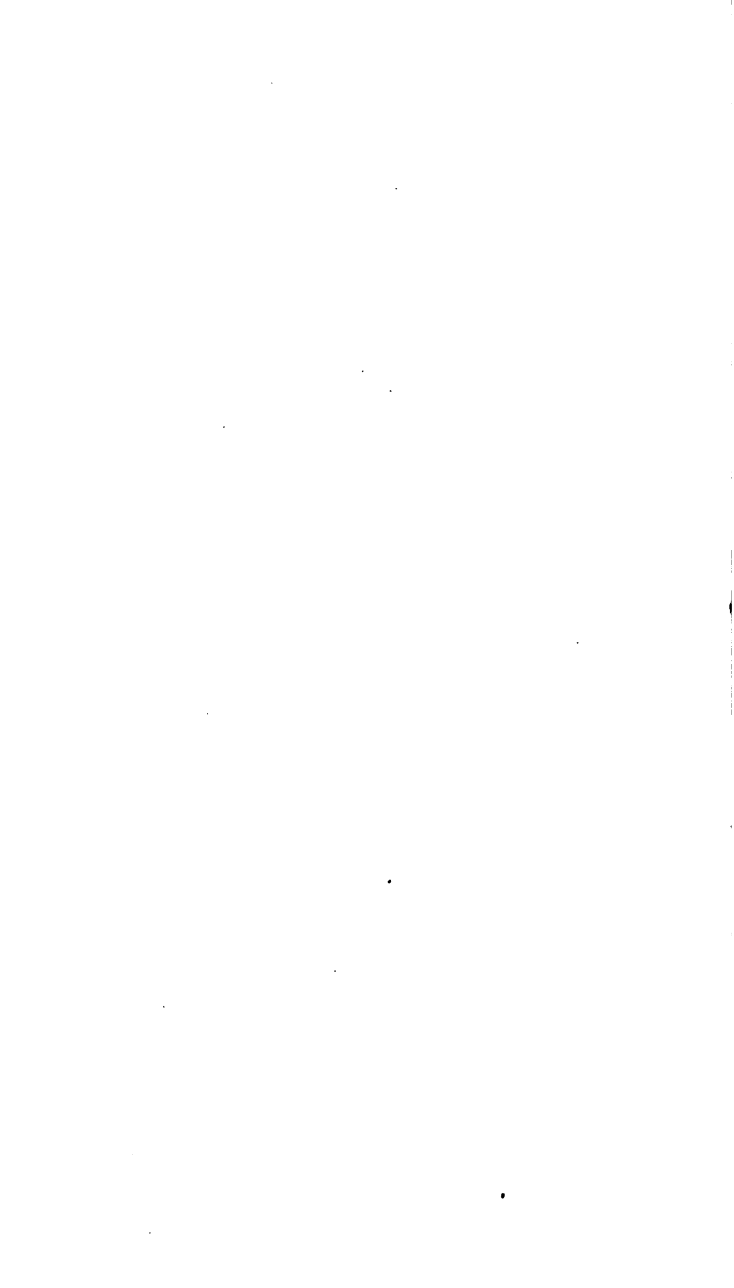
Cosine of angle = .903 21. Then $1 \div .903\ 21 = 1.1072$, Secant.

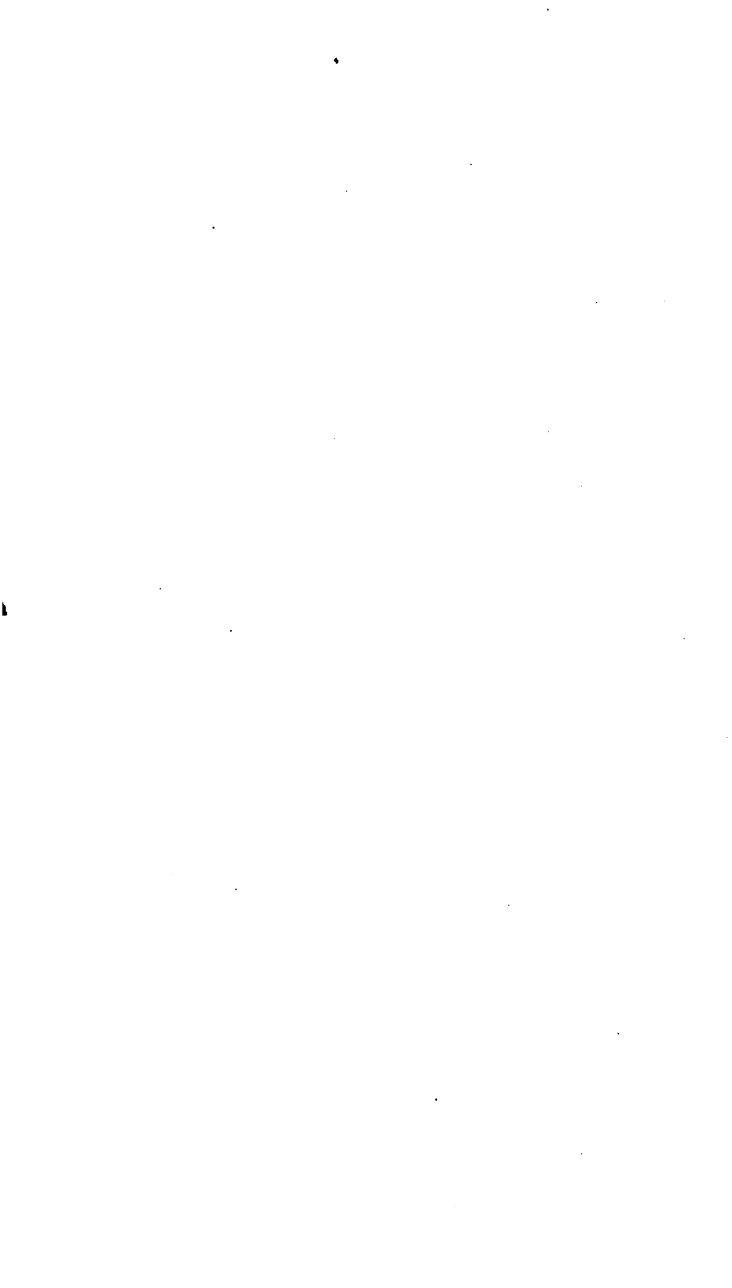
2.—What is co-secant of $64^{\circ} 35'$?

Sine of angle = .903 21. Then $1 \div .903\ 21 = 1.1072$, Co-secant.

From Haswell's "Engineering."

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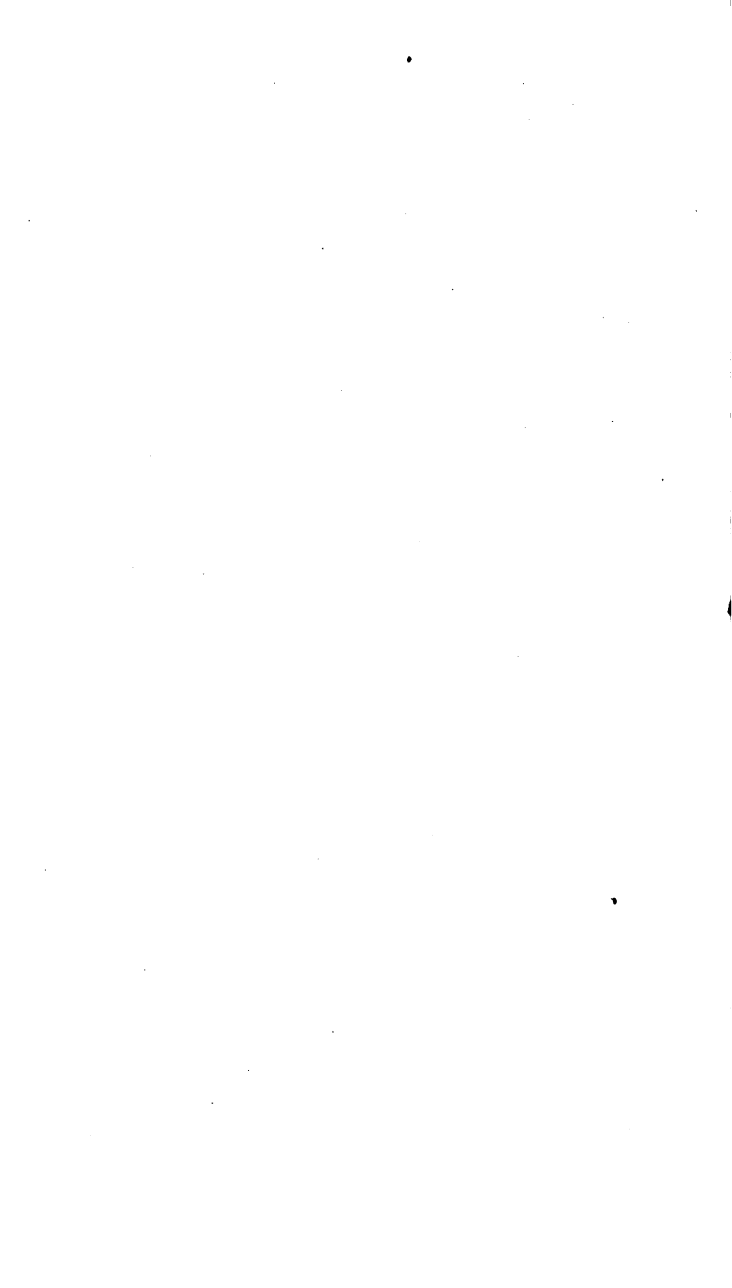


TABLE XII.—TANGENTS AND COTANGENTS.

	0°		1°		2°		3°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	00000	Infinite.	01746	57.2900	03492	28.6363	05241	19.0811	60
1	00029	3437.75	01775	56.8506	03521	28.3994	05270	18.9755	59
2	00058	1718.87	01804	55.4415	03550	28.1664	05299	18.8711	58
3	00087	1145.92	01833	54.5618	03579	27.9372	05328	18.7678	57
4	00116	859.436	01862	53.7086	03609	27.7117	05357	18.6656	56
5	00145	687.549	01891	52.8821	03638	27.4899	05387	18.5645	55
6	00175	572.957	01920	52.0807	03667	27.2715	05416	18.4645	54
7	00204	491.106	01949	51.3032	03696	27.0566	05445	18.3655	53
8	00233	429.718	01978	50.5485	03725	26.8450	05474	18.2677	52
9	00262	381.971	02007	49.8157	03754	26.6367	05503	18.1708	51
10	00291	343.774	02036	49.1089	03783	26.4316	05533	18.0750	50
11	00320	312.521	02066	48.4121	03812	26.2296	05562	17.9802	49
12	00349	286.478	02095	47.7395	03842	26.0307	05591	17.8863	48
13	00378	264.441	02124	47.0853	03871	25.8348	05620	17.7934	47
14	00407	245.552	02153	46.4489	03900	25.6418	05649	17.7015	46
15	00436	229.182	02182	45.8294	03929	25.4517	05678	17.6106	45
16	00465	214.858	02211	45.2261	03958	25.2644	05708	17.5205	44
17	00495	202.219	02240	44.6386	03987	25.0798	05737	17.4314	43
18	00524	190.984	02269	44.0661	04016	24.8978	05766	17.3432	42
19	00553	180.932	02298	43.5081	04046	24.7185	05795	17.2558	41
20	00582	171.885	02328	42.9641	04075	24.5418	05824	17.1698	40
21	00611	163.700	02357	42.4335	04104	24.3675	05854	17.0837	39
22	00640	156.259	02386	41.9158	04133	24.1957	05883	16.9990	38
23	00669	149.465	02415	41.4106	04162	24.0263	05912	16.9150	37
24	00698	143.287	02444	40.9174	04191	23.8593	05941	16.8319	36
25	00727	137.507	02473	40.4358	04220	23.6945	05970	16.7496	35
26	00756	132.219	02502	39.9655	04250	23.5321	05999	16.6681	34
27	00785	127.821	02531	39.5059	04279	23.3718	06029	16.5874	33
28	00815	122.774	02560	39.0568	04308	23.2137	06058	16.5075	32
29	00844	118.540	02589	38.6177	04337	23.0577	06087	16.4288	31
30	00873	114.589	02619	38.1885	04366	22.9038	06116	16.3499	30
31	00902	110.892	02648	37.7686	04395	22.7519	06145	16.2722	29
32	00931	107.426	02677	37.3579	04424	22.6020	06175	16.1952	28
33	00960	104.171	02706	36.9560	04453	22.4541	06204	16.1190	27
34	00989	101.107	02735	36.5627	04483	22.3081	06233	16.0435	26
35	01018	98.2179	02764	36.1776	04512	22.1640	06262	15.9687	25
36	01047	95.4895	02793	35.8006	04541	22.0217	06291	15.8945	24
37	01076	92.9066	02822	35.4313	04570	21.8813	06321	15.8211	23
38	01105	90.4683	02851	35.0695	04599	21.7426	06350	15.7483	22
39	01135	88.1436	02881	34.7151	04628	21.6056	06379	15.6762	21
40	01164	85.9398	02910	34.3678	04658	21.4704	06408	15.6048	20
41	01193	83.8435	02939	34.0273	04687	21.3369	06437	15.5340	19
42	01222	81.8470	02968	33.6935	04716	21.2049	06467	15.4638	18
43	01251	79.9434	02997	33.3662	04745	21.0747	06496	15.3943	17
44	01280	78.1263	03026	33.0452	04774	20.9460	06525	15.3254	16
45	01309	76.3900	03055	32.7303	04803	20.8188	06554	15.2571	15
46	01338	74.7292	03084	32.4213	04833	20.6932	06584	15.1893	14
47	01367	73.1390	03114	32.1181	04862	20.5691	06613	15.1222	13
48	01396	71.6151	03143	31.8205	04891	20.4465	06642	15.0567	12
49	01425	70.1533	03172	31.5284	04920	20.3253	06671	14.9928	11
50	01455	68.7501	03201	31.2416	04949	20.2056	06700	14.9244	10
51	01484	67.4019	03230	30.9599	04978	20.0872	06730	14.8596	9
52	01513	66.1055	03259	30.6833	05007	19.9702	06759	14.7954	8
53	01542	64.8580	03288	30.4116	05037	19.8546	06788	14.7317	7
54	01571	63.6587	03317	30.1446	05066	19.7403	06817	14.6685	6
55	01600	62.4992	03346	29.8823	05095	19.6273	06847	14.6059	5
56	01629	61.3829	03376	29.6245	05124	19.5156	06876	14.5438	4
57	01658	60.3058	03405	29.3711	05153	19.4051	06905	14.4823	3
58	01687	59.2659	03434	29.1220	05182	19.2959	06934	14.4212	2
59	01716	58.2612	03463	28.8771	05212	19.1879	06963	14.3607	1
60	01746	57.2900	03492	28.6363	05241	19.0811	06993	14.3007	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	89°		88°		87°		86°		

TABLE XII.—TANGENTS AND COTANGENTS.

	4°		5°		6°		7°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.06993	14.3007	08749	11.4301	10510	9.51486	12278	8.14435	60
1	07022	14.2411	08778	11.3919	10540	9.48781	12308	8.12481	59
2	07051	14.1821	08807	11.3540	10569	9.46141	12338	8.10586	58
3	07080	14.1235	08837	11.3163	10599	9.43515	12367	8.08600	57
4	07110	14.0655	08866	11.2789	10628	9.40904	12397	8.06674	56
5	07139	14.0079	08895	11.2417	10657	9.38307	12426	8.04756	55
6	07168	13.9507	08925	11.2048	10687	9.35724	12456	8.02848	54
7	07197	13.8940	08954	11.1681	10716	9.33155	12485	8.00948	53
8	07227	13.8378	08983	11.1316	10746	9.30599	12515	7.99058	52
9	07256	13.7821	09013	11.0954	10775	9.28058	12544	7.97176	51
10	07285	13.7267	09042	11.0594	10805	9.25530	12574	7.95302	50
11	07314	13.6719	09071	11.0237	10834	9.23016	12603	7.93488	49
12	07344	13.6174	09101	10.9882	10863	9.20516	12633	7.91582	48
13	07373	13.5634	09130	10.9529	10893	9.18028	12662	7.89734	47
14	07402	13.5098	09159	10.9178	10922	9.15554	12692	7.87895	46
15	07431	13.4566	09189	10.8829	10952	9.13093	12722	7.86004	45
16	07461	13.4039	09218	10.8483	10981	9.10646	12751	7.84242	44
17	07490	13.3515	09247	10.8139	11011	9.08211	12781	7.82428	43
18	07519	13.2996	09277	10.7797	11040	9.05789	12810	7.80622	42
19	07548	13.2480	09306	10.7457	11070	9.03379	12840	7.78825	41
20	07578	13.1969	09335	10.7119	11099	9.00983	12869	7.77085	40
21	07607	13.1461	09365	10.6783	11128	8.98598	12899	7.75254	39
22	07636	13.0958	09394	10.6450	11158	8.96227	12929	7.73480	38
23	07665	13.0458	09423	10.6118	11187	8.93867	12958	7.71715	37
24	07695	12.9962	09453	10.5789	11217	8.91520	12988	7.69957	36
25	07724	12.9469	09482	10.5462	11246	8.89185	13017	7.68208	35
26	07753	12.8981	09511	10.5136	11276	8.86862	13047	7.66466	34
27	07782	12.8496	09541	10.4813	11305	8.84551	13076	7.64732	33
28	07812	12.8014	09570	10.4491	11335	8.82252	13106	7.63005	32
29	07841	12.7536	09600	10.4172	11364	8.79964	13136	7.61287	31
30	07870	12.7062	09629	10.3854	11394	8.77689	13165	7.59575	30
31	07899	12.6591	09658	10.3538	11423	8.75425	13195	7.57872	29
32	07929	12.6124	09688	10.3224	11452	8.73172	13224	7.56176	28
33	07958	12.5660	09717	10.2913	11482	8.70931	13254	7.54487	27
34	07987	12.5199	09746	10.2602	11511	8.68701	13284	7.52806	26
35	08017	12.4742	09776	10.2294	11541	8.66482	13313	7.51182	25
36	08046	12.4288	09805	10.1988	11570	8.64275	13343	7.49465	24
37	08075	12.3838	09834	10.1683	11600	8.62078	13373	7.47806	23
38	08104	12.3390	09864	10.1381	11629	8.59893	13402	7.46154	22
39	08134	12.2946	09893	10.1080	11659	8.57718	13432	7.44509	21
40	08163	12.2505	09923	10.0780	11688	8.55555	13461	7.42871	20
41	08192	12.2067	09952	10.0483	11718	8.53402	13491	7.41240	19
42	08221	12.1632	09981	10.0187	11747	8.51259	13521	7.39616	18
43	08251	12.1201	10011	9.98931	11777	8.49128	13550	7.37999	17
44	08280	12.0772	10040	9.96007	11806	8.47007	13580	7.36389	16
45	08309	12.0346	10069	9.93101	11836	8.44896	13609	7.34786	15
46	08339	11.9923	10099	9.90211	11865	8.42795	13639	7.33190	14
47	08368	11.9504	10128	9.87338	11895	8.40705	13669	7.31600	13
48	08397	11.9087	10158	9.84482	11924	8.38625	13698	7.30018	12
49	08427	11.8673	10187	9.81641	11954	8.36555	13728	7.28442	11
50	08456	11.8262	10216	9.78817	11983	8.34496	13758	7.26873	10
51	08485	11.7853	10246	9.76009	12013	8.32446	13787	7.25310	9
52	08514	11.7448	10275	9.73217	12042	8.30406	13817	7.23754	8
53	08544	11.7045	10305	9.70441	12072	8.28376	13846	7.22204	7
54	08573	11.6645	10334	9.67680	12101	8.26355	13876	7.20661	6
55	08602	11.6248	10363	9.64935	12131	8.24345	13906	7.19125	5
56	08632	11.5853	10393	9.62205	12160	8.22344	13935	7.17594	4
57	08661	11.5461	10422	9.59490	12190	8.20352	13965	7.16071	3
58	08690	11.5072	10452	9.56791	12219	8.18370	13995	7.14553	2
59	08720	11.4685	10481	9.54106	12249	8.16398	14024	7.13042	1
60	08749	11.4301	10510	9.51436	12278	8.14435	14054	7.11537	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	85°		84°		83°		82°		

TABLE XII.—TANGENTS AND COTANGENTS.

	8°		9°		10°		11°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	14054	7.11537	15838	6.31375	17633	5.67128	19436	5.14455	60
1	14084	7.10088	15968	6.30189	17663	5.66165	19468	5.13658	59
2	14113	7.08546	15898	6.29007	17693	5.65205	19498	5.12862	58
3	14143	7.07059	15928	6.27829	17723	5.64248	19529	5.12069	57
4	14173	7.05579	15958	6.26655	17753	5.63295	19559	5.11279	56
5	14202	7.04105	15988	6.25486	17783	5.62344	19589	5.10490	55
6	14232	7.02637	16017	6.24321	17813	5.61397	19619	5.09704	54
7	14262	6.91174	16047	6.23160	17843	5.60452	19649	5.08921	53
8	14291	6.90718	16077	6.22008	17873	5.59511	19680	5.08139	52
9	14321	6.90268	16107	6.20851	17903	5.58573	19710	5.07360	51
10	14351	6.90823	16137	6.19703	17933	5.57638	19740	5.06584	50
11	14381	6.90385	16167	6.18559	17963	5.56706	19770	5.05809	49
12	14410	6.90952	16196	6.17419	17993	5.55777	19801	5.05037	48
13	14440	6.92525	16226	6.16283	18023	5.54851	19831	5.04267	47
14	14470	6.91104	16256	6.15151	18053	5.53927	19861	5.03499	46
15	14499	6.89688	16286	6.14023	18083	5.53007	19891	5.02734	45
16	14529	6.88278	16316	6.12899	18113	5.52090	19921	5.01971	44
17	14559	6.86874	16346	6.11779	18143	5.51176	19952	5.01210	43
18	14588	6.85475	16376	6.10664	18173	5.50264	19982	5.00451	42
19	14618	6.84082	16405	6.09552	18203	5.49356	20012	4.99695	41
20	14648	6.82694	16435	6.08444	18233	5.48451	20042	4.98940	40
21	14678	6.81312	16465	6.07340	18263	5.47548	20073	4.98188	39
22	14707	6.79936	16495	6.06240	18293	5.46648	20103	4.97438	38
23	14737	6.78564	16525	6.05143	18323	5.45751	20133	4.96690	37
24	14767	6.77199	16555	6.04051	18353	5.44857	20164	4.95945	36
25	14796	6.75838	16585	6.02962	18384	5.43966	20194	4.95201	35
26	14826	6.74483	16615	6.01878	18414	5.43077	20224	4.94460	34
27	14856	6.73133	16645	6.00797	18444	5.42192	20254	4.93721	33
28	14886	6.71789	16674	5.99720	18474	5.41309	20285	4.92984	32
29	14915	6.70450	16704	5.98646	18504	5.40429	20315	4.92249	31
30	14945	6.69116	16734	5.97576	18534	5.39552	20345	4.91516	30
31	14975	6.67787	16764	5.96510	18564	5.38677	20376	4.90785	29
32	15005	6.66463	16794	5.95448	18594	5.37805	20406	4.90056	28
33	15034	6.65144	16824	5.94390	18624	5.36936	20436	4.89330	27
34	15064	6.63831	16854	5.93335	18654	5.36070	20466	4.88605	26
35	15094	6.62523	16884	5.92283	18684	5.35206	20497	4.87882	25
36	15124	6.61219	16914	5.91236	18714	5.34345	20527	4.87162	24
37	15153	6.59921	16944	5.90191	18745	5.33487	20557	4.86444	23
38	15183	6.58627	16974	5.89151	18775	5.32631	20588	4.85727	22
39	15213	6.57339	17004	5.88114	18805	5.31778	20618	4.85013	21
40	15243	6.56055	17033	5.87080	18835	5.30928	20648	4.84300	20
41	15272	6.54777	17063	5.86051	18865	5.30080	20679	4.83590	19
42	15302	6.53503	17093	5.85024	18895	5.29235	20709	4.82882	18
43	15332	6.52234	17123	5.84001	18925	5.28393	20739	4.82175	17
44	15362	6.50970	17153	5.82982	18955	5.27553	20770	4.81471	16
45	15391	6.49710	17183	5.81966	18986	5.26715	20800	4.80769	15
46	15421	6.48456	17213	5.80953	19016	5.25880	20830	4.80068	14
47	15451	6.47206	17243	5.79944	19046	5.25048	20861	4.79370	13
48	15481	6.45961	17273	5.78938	19076	5.24218	20891	4.78673	12
49	15511	6.44720	17303	5.77936	19106	5.23391	20921	4.77978	11
50	15540	6.43484	17333	5.76937	19136	5.22566	20952	4.77286	10
51	15570	6.42253	17363	5.75941	19166	5.21744	20982	4.76595	9
52	15600	6.41026	17393	5.74949	19197	5.20925	21013	4.75906	8
53	15630	6.39804	17423	5.73960	19227	5.20107	21043	4.75219	7
54	15660	6.38587	17453	5.72974	19257	5.19293	21073	4.74534	6
55	15689	6.37374	17483	5.71992	19287	5.18480	21104	4.73851	5
56	15719	6.36165	17513	5.71013	19317	5.17671	21134	4.73170	4
57	15749	6.34961	17543	5.70037	19347	5.16863	21164	4.72490	3
58	15779	6.33761	17573	5.69064	19378	5.16058	21195	4.71813	2
59	15809	6.32566	17603	5.68094	19408	5.15256	21225	4.71137	1
60	15838	6.31375	17633	5.67128	19438	5.14455	21256	4.70463	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	81°		80°		79°		78°		

TABLE XII.—TANGENTS AND COTANGENTS.

	12°		13°		14°		15°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	21256	4.70468	28087	4.38148	24938	4.01078	26795	3.73205	60
1	21286	4.69791	28117	4.38573	24964	4.00582	26826	3.72771	59
2	21316	4.69121	28148	4.38001	24985	4.00086	26857	3.72338	58
3	21347	4.68452	28179	4.31430	25026	3.99592	26888	3.71907	57
4	21377	4.67786	28209	4.30860	25056	3.99099	26920	3.71476	56
5	21408	4.67121	28240	4.30291	25087	3.98607	26951	3.71046	55
6	21438	4.66458	28271	4.29724	25118	3.98117	26982	3.70616	54
7	21469	4.65797	28301	4.29159	25149	3.97627	27013	3.70188	53
8	21499	4.65138	28332	4.28595	25180	3.97139	27044	3.69761	52
9	21529	4.64480	28363	4.28032	25211	3.96651	27076	3.69335	51
10	21560	4.63825	28393	4.27471	25242	3.96165	27107	3.68909	50
11	21590	4.63171	28424	4.26911	25273	3.95680	27138	3.68485	49
12	21621	4.62518	28455	4.26352	25304	3.95196	27169	3.68061	48
13	21651	4.61868	28485	4.25795	25335	3.94713	27201	3.67638	47
14	21682	4.61219	28516	4.25239	25366	3.94232	27232	3.67217	46
15	21712	4.60572	28547	4.24685	25397	3.93751	27263	3.66796	45
16	21743	4.59927	28578	4.24132	25428	3.93271	27294	3.66376	44
17	21773	4.59283	28608	4.23580	25459	3.92793	27326	3.65957	43
18	21804	4.58641	28639	4.23030	25490	3.92316	27357	3.65538	42
19	21834	4.58001	28670	4.22481	25521	3.91839	27388	3.65121	41
20	21864	4.57363	28700	4.21933	25552	3.91364	27419	3.64705	40
21	21895	4.56726	28731	4.21387	25583	3.90890	27451	3.64289	39
22	21925	4.56091	28762	4.20842	25614	3.90417	27482	3.63874	38
23	21956	4.55458	28793	4.20298	25645	3.89945	27513	3.63461	37
24	21986	4.54826	28823	4.19756	25676	3.89474	27545	3.63048	36
25	22017	4.54196	28854	4.19215	25707	3.89004	27576	3.62636	35
26	22047	4.53568	28885	4.18675	25738	3.88536	27607	3.62224	34
27	22078	4.52941	28916	4.18137	25769	3.88068	27638	3.61814	33
28	22108	4.52316	28946	4.17600	25800	3.87601	27670	3.61406	32
29	22139	4.51693	28977	4.17064	25831	3.87136	27701	3.60996	31
30	22169	4.51071	29008	4.16530	25862	3.86671	27732	3.60588	30
31	22200	4.50451	29039	4.15997	25893	3.86208	27764	3.60181	29
32	22231	4.49832	29069	4.15465	25924	3.85745	27795	3.59775	28
33	22261	4.49215	29100	4.14934	25955	3.85284	27826	3.59370	27
34	22292	4.48600	29131	4.14405	25986	3.84824	27858	3.58966	26
35	22322	4.47986	29162	4.13877	26017	3.84364	27889	3.58562	25
36	22353	4.47374	29193	4.13350	26048	3.83906	27921	3.58160	24
37	22383	4.46764	29223	4.12825	26079	3.83449	27952	3.57758	23
38	22414	4.46155	29254	4.12301	26110	3.82992	27983	3.57357	22
39	22444	4.45548	29285	4.11778	26141	3.82537	28015	3.56957	21
40	22475	4.44942	29316	4.11256	26172	3.82083	28046	3.56557	20
41	22505	4.44338	29347	4.10736	26203	3.81630	28077	3.56159	19
42	22536	4.43735	29377	4.10216	26235	3.81177	28109	3.55761	18
43	22567	4.43134	29408	4.09699	26266	3.80726	28140	3.55364	17
44	22597	4.42534	29439	4.09182	26297	3.80276	28172	3.54968	16
45	22628	4.41936	29470	4.08666	26328	3.79827	28203	3.54573	15
46	22658	4.41340	29501	4.08152	26359	3.79378	28234	3.54179	14
47	22689	4.40745	29532	4.07639	26390	3.78931	28266	3.53785	13
48	22719	4.40152	29562	4.07127	26421	3.78485	28297	3.53393	12
49	22750	4.39560	29593	4.06616	26452	3.78040	28329	3.53001	11
50	22781	4.38969	29624	4.06107	26483	3.77595	28360	3.52609	10
51	22811	4.38381	29655	4.05599	26515	3.77152	28391	3.52219	9
52	22842	4.37793	29686	4.05092	26546	3.76709	28423	3.51829	8
53	22872	4.37207	29717	4.04586	26577	3.76268	28454	3.51441	7
54	22903	4.36623	29747	4.04081	26608	3.75828	28486	3.51053	6
55	22934	4.36040	29778	4.03578	26639	3.75388	28517	3.50666	5
56	22964	4.35459	29809	4.03076	26670	3.74950	28549	3.50279	4
57	22995	4.34879	29840	4.02574	26701	3.74512	28580	3.49894	3
58	23026	4.34300	29871	4.02074	26733	3.74075	28612	3.49509	2
59	23056	4.33723	29902	4.01576	26764	3.73640	28643	3.49125	1
60	23087	4.33148	29933	4.01078	26795	3.73205	28675	3.48741	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	77°		76°		75°		74°		

TABLE XII.—TANGENTS AND COTANGENTS.

	16°		17°		18°		19°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	28675	3.48741	30573	3.27085	32492	3.07768	34433	2.90421	60
1	28706	3.48359	30605	3.26745	32524	3.07464	34465	2.90147	59
2	28738	3.47977	30637	3.26406	32556	3.07160	34498	2.89873	58
3	28769	3.47596	30669	3.26067	32588	3.06857	34530	2.89600	57
4	28800	3.47216	30700	3.25729	32621	3.06554	34563	2.89327	56
5	28832	3.46837	30732	3.25392	32653	3.06252	34596	2.89055	55
6	28864	3.46458	30764	3.25055	32685	3.05950	34628	2.88783	54
7	28895	3.46080	30796	3.24719	32717	3.05649	34661	2.88511	53
8	28927	3.45703	30828	3.24383	32749	3.05349	34693	2.88240	52
9	28958	3.45327	30860	3.24049	32782	3.05049	34726	2.87970	51
10	28990	3.44951	30891	3.23714	32814	3.04749	34758	2.87700	50
11	29021	3.44576	30923	3.23381	32846	3.04450	34791	2.87430	49
12	29053	3.44202	30955	3.23048	32878	3.04152	34824	2.87161	48
13	29084	3.43829	30987	3.22715	32911	3.03854	34856	2.86892	47
14	29116	3.43456	31019	3.22384	32943	3.03556	34889	2.86624	46
15	29147	3.43084	31051	3.22053	32975	3.03260	34922	2.86356	45
16	29179	3.42713	31083	3.21722	33007	3.02963	34954	2.86089	44
17	29210	3.42343	31115	3.21392	33040	3.02667	34987	2.85822	43
18	29242	3.41973	31147	3.21063	33072	3.02372	35020	2.85555	42
19	29274	3.41604	31178	3.20734	33104	3.02077	35052	2.85289	41
20	29305	3.41236	31210	3.20406	33136	3.01783	35085	2.85023	40
21	29337	3.40869	31242	3.20079	33169	3.01489	35118	2.84758	39
22	29368	3.40502	31274	3.19752	33201	3.01196	35150	2.84494	38
23	29400	3.40136	31306	3.19426	33233	3.00903	35183	2.84229	37
24	29432	3.39771	31338	3.19100	33266	3.00611	35216	2.83965	36
25	29463	3.39406	31370	3.18775	33298	3.00319	35248	2.83702	35
26	29495	3.39042	31402	3.18451	33330	3.00028	35281	2.83439	34
27	29526	3.38679	31434	3.18127	33363	2.99738	35314	2.83176	33
28	29558	3.38317	31466	3.17804	33395	2.99447	35346	2.82914	32
29	29590	3.37955	31498	3.17481	33427	2.99158	35379	2.82653	31
30	29621	3.37594	31530	3.17159	33460	2.98868	35412	2.82391	30
31	29653	3.37234	31562	3.16838	33492	2.98580	35445	2.82130	29
32	29685	3.36875	31594	3.16517	33524	2.98292	35477	2.81870	28
33	29716	3.36516	31626	3.16197	33557	2.98004	35510	2.81610	27
34	29748	3.36158	31658	3.15877	33589	2.97717	35543	2.81350	26
35	29780	3.35800	31690	3.15558	33621	2.97430	35576	2.81091	25
36	29811	3.35443	31722	3.15240	33654	2.97144	35608	2.80833	24
37	29843	3.35087	31754	3.14923	33686	2.96858	35641	2.80574	23
38	29875	3.34732	31786	3.14605	33718	2.96573	35674	2.80316	22
39	29906	3.34377	31818	3.14288	33751	2.96288	35707	2.80059	21
40	29938	3.34023	31850	3.13972	33783	2.96004	35740	2.79802	20
41	29970	3.33670	31882	3.13656	33816	2.95721	35772	2.79545	19
42	30001	3.33317	31914	3.13341	33848	2.95437	35805	2.79289	18
43	30033	3.32965	31946	3.13027	33881	2.95155	35838	2.79033	17
44	30065	3.32614	31978	3.12713	33913	2.94873	35871	2.78778	16
45	30097	3.32264	32010	3.12400	33945	2.94591	35904	2.78523	15
46	30128	3.31914	32042	3.12087	33978	2.94309	35937	2.78269	14
47	30160	3.31565	32074	3.11775	34010	2.94028	35969	2.78014	13
48	30192	3.31216	32106	3.11464	34043	2.93748	36002	2.77761	12
49	30224	3.30868	32139	3.11153	34075	2.93468	36035	2.77507	11
50	30255	3.30521	32171	3.10842	34108	2.93189	36068	2.77254	10
51	30287	3.30174	32203	3.10532	34140	2.92910	36101	2.77002	9
52	30319	3.29829	32235	3.10223	34173	2.92632	36134	2.76750	8
53	30351	3.29483	32267	3.09914	34205	2.92354	36167	2.76498	7
54	30382	3.29139	32299	3.09606	34238	2.92076	36199	2.76247	6
55	30414	3.28795	32331	3.09298	34270	2.91799	36232	2.75996	5
56	30446	3.28452	32363	3.08991	34303	2.91523	36265	2.75746	4
57	30478	3.28109	32396	3.08685	34335	2.91246	36298	2.75496	3
58	30509	3.27767	32428	3.08379	34368	2.90971	36331	2.75246	2
59	30541	3.27426	32460	3.08073	34400	2.90696	36364	2.74997	1
60	30573	3.27085	32492	3.07768	34433	2.90421	36397	2.74748	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	73°		72°		71°		70°		

TABLE XII.—TANGENTS AND COTANGENTS.

	20°		21°		22°		23°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	36397	2.74748	38386	2.60509	40403	2.47509	42447	2.35535	60
1	36430	2.74499	38420	2.60283	40436	2.47302	42483	2.35395	59
2	36463	2.74251	38453	2.60057	40470	2.47095	42516	2.35205	58
3	36496	2.74004	38487	2.59831	40504	2.46888	42551	2.35015	57
4	36529	2.73756	38520	2.59606	40538	2.46682	42585	2.34825	56
5	36562	2.73509	38553	2.59381	40572	2.46476	42619	2.34636	55
6	36595	2.73263	38587	2.59156	40606	2.46270	42654	2.34447	54
7	36628	2.73017	38620	2.58932	40640	2.46065	42688	2.34258	53
8	36661	2.72771	38654	2.58708	40674	2.45860	42722	2.34069	52
9	36694	2.72526	38687	2.58484	40707	2.45655	42757	2.33881	51
10	36727	2.72281	38721	2.58261	40741	2.45451	42791	2.33693	50
11	36760	2.72036	38754	2.58038	40775	2.45246	42826	2.33505	49
12	36793	2.71792	38787	2.57815	40809	2.45043	42860	2.33317	48
13	36826	2.71548	38821	2.57593	40843	2.44839	42894	2.33130	47
14	36859	2.71305	38854	2.57371	40877	2.44636	42929	2.32942	46
15	36892	2.71062	38888	2.57150	40911	2.44433	42963	2.32756	45
16	36925	2.70819	38921	2.56928	40945	2.44230	42998	2.32570	44
17	36958	2.70577	38955	2.56707	40979	2.44027	43032	2.32383	43
18	36991	2.70335	38988	2.56487	41013	2.43825	43067	2.32197	42
19	37024	2.70094	39022	2.56266	41047	2.43623	43101	2.32012	41
20	37057	2.69853	39055	2.56046	41081	2.43422	43136	2.31826	40
21	37090	2.69612	39089	2.55827	41115	2.43220	43170	2.31641	39
22	37123	2.69371	39123	2.55608	41149	2.43019	43205	2.31456	38
23	37157	2.69131	39156	2.55389	41183	2.42819	43239	2.31271	37
24	37190	2.68892	39190	2.55170	41217	2.42618	43274	2.31086	36
25	37223	2.68653	39223	2.54952	41251	2.42418	43308	2.30902	35
26	37256	2.68414	39257	2.54734	41285	2.42218	43343	2.30718	34
27	37289	2.68175	39290	2.54516	41319	2.42019	43378	2.30534	33
28	37322	2.67937	39324	2.54299	41353	2.41819	43412	2.30351	32
29	37355	2.67700	39357	2.54082	41387	2.41620	43447	2.30167	31
30	37388	2.67462	39391	2.53865	41421	2.41421	43481	2.29984	30
31	37422	2.67225	39425	2.53648	41455	2.41223	43516	2.29801	29
32	37455	2.66989	39458	2.53432	41490	2.41025	43550	2.29619	28
33	37488	2.66752	39492	2.53217	41524	2.40827	43585	2.29437	27
34	37521	2.66516	39526	2.53001	41558	2.40629	43620	2.29254	26
35	37554	2.66281	39559	2.52786	41592	2.40432	43654	2.29073	25
36	37588	2.66046	39593	2.52571	41626	2.40235	43689	2.28891	24
37	37621	2.65811	39626	2.52357	41660	2.40038	43724	2.28710	23
38	37654	2.65576	39660	2.52142	41694	2.39841	43758	2.28528	22
39	37687	2.65342	39694	2.51929	41728	2.39645	43793	2.28348	21
40	37720	2.65109	39727	2.51715	41763	2.39449	43828	2.28167	20
41	37754	2.64875	39761	2.51502	41797	2.39253	43863	2.27987	19
42	37787	2.64642	39795	2.51289	41831	2.39058	43897	2.27806	18
43	37820	2.64410	39829	2.51076	41865	2.38863	43932	2.27626	17
44	37853	2.64177	39862	2.50864	41899	2.38668	43966	2.27447	16
45	37887	2.63945	39896	2.50652	41933	2.38473	44001	2.27267	15
46	37920	2.63714	39930	2.50440	41968	2.38279	44036	2.27088	14
47	37953	2.63483	39963	2.50229	42002	2.38084	44071	2.26909	13
48	37986	2.63252	39997	2.50018	42036	2.37891	44105	2.26730	12
49	38020	2.63021	40031	2.49807	42070	2.37697	44140	2.26552	11
50	38053	2.62791	40065	2.49597	42105	2.37504	44175	2.26374	10
51	38086	2.62561	40098	2.49386	42139	2.37311	44210	2.26196	9
52	38120	2.62332	40132	2.49177	42173	2.37118	44244	2.26018	8
53	38153	2.62103	40166	2.48967	42207	2.36925	44279	2.25840	7
54	38186	2.61874	40200	2.48758	42242	2.36733	44314	2.25663	6
55	38220	2.61646	40234	2.48549	42276	2.36541	44349	2.25486	5
56	38253	2.61418	40267	2.48340	42310	2.36349	44384	2.25309	4
57	38286	2.61190	40301	2.48132	42345	2.36158	44418	2.25132	3
58	38320	2.60963	40335	2.47924	42379	2.35967	44453	2.24956	2
59	38353	2.60736	40369	2.47716	42413	2.35776	44488	2.24780	1
60	38386	2.60509	40403	2.47509	42447	2.35585	44523	2.24604	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	69°		68°		67°		66°		

TABLE XII.—TANGENTS AND COTANGENTS.

	24°		25°		26°		27°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	44523	2.24004	46631	2.14451	48773	2.05080	50958	1.96261	60
1	44558	2.24428	46666	2.14288	48809	2.04879	50989	1.96120	59
2	44593	2.24852	46702	2.14125	48845	2.04728	51026	1.95979	58
3	44627	2.24077	46737	2.13963	48881	2.04577	51063	1.95838	57
4	44662	2.23902	46772	2.13801	48917	2.04426	51099	1.95698	56
5	44697	2.23727	46808	2.13639	48953	2.04276	51136	1.95557	55
6	44732	2.23553	46843	2.13477	48989	2.04125	51173	1.95417	54
7	44767	2.23378	46879	2.13316	49026	2.03975	51209	1.95277	53
8	44802	2.23204	46914	2.13154	49062	2.03825	51246	1.95137	52
9	44837	2.23030	46950	2.12993	49098	2.03675	51283	1.94997	51
10	44872	2.22857	46985	2.12832	49134	2.03526	51319	1.94858	50
11	44907	2.22683	47021	2.12671	49170	2.03376	51356	1.94718	49
12	44942	2.22510	47056	2.12511	49206	2.03227	51393	1.94579	48
13	44977	2.22337	47092	2.12350	49242	2.03078	51430	1.94440	47
14	45012	2.22164	47128	2.12190	49278	2.02929	51467	1.94301	46
15	45047	2.21992	47163	2.12030	49315	2.02780	51503	1.94162	45
16	45082	2.21819	47199	2.11871	49351	2.02631	51540	1.94023	44
17	45117	2.21647	47234	2.11711	49387	2.02483	51577	1.93885	43
18	45152	2.21475	47270	2.11552	49423	2.02335	51614	1.93746	42
19	45187	2.21304	47305	2.11392	49459	2.02187	51651	1.93608	41
20	45222	2.21132	47341	2.11233	49495	2.02039	51688	1.93470	40
21	45257	2.20961	47377	2.11075	49532	2.01891	51724	1.93332	39
22	45292	2.20790	47412	2.10916	49568	2.01743	51761	1.93195	38
23	45327	2.20619	47448	2.10758	49604	2.01596	51798	1.93057	37
24	45362	2.20449	47483	2.10600	49640	2.01449	51835	1.92920	36
25	45397	2.20278	47519	2.10442	49677	2.01302	51872	1.92782	35
26	45432	2.20108	47555	2.10284	49713	2.01155	51909	1.92645	34
27	45467	2.19938	47590	2.10126	49749	2.01008	51946	1.92508	33
28	45502	2.19769	47626	2.09969	49786	2.00862	51983	1.92371	32
29	45538	2.19599	47662	2.09811	49822	2.00715	52020	1.92235	31
30	45573	2.19430	47698	2.09654	49858	2.00569	52057	1.92098	30
31	45608	2.19261	47733	2.09498	49894	2.00423	52094	1.91962	29
32	45643	2.19092	47769	2.09341	49931	2.00277	52131	1.91826	28
33	45678	2.18923	47805	2.09184	49967	2.00131	52168	1.91690	27
34	45713	2.18755	47840	2.09028	50004	1.99986	52205	1.91554	26
35	45748	2.18587	47876	2.08872	50040	1.99841	52242	1.91418	25
36	45784	2.18419	47912	2.08716	50076	1.99695	52279	1.91282	24
37	45819	2.18251	47948	2.08560	50113	1.99550	52316	1.91147	23
38	45854	2.18084	47984	2.08405	50149	1.99406	52353	1.91012	22
39	45889	2.17916	48019	2.08250	50185	1.99261	52390	1.90876	21
40	45924	2.17749	48055	2.08094	50222	1.99116	52427	1.90741	20
41	45960	2.17582	48091	2.07939	50258	1.98972	52464	1.90607	19
42	45995	2.17416	48127	2.07785	50295	1.98828	52501	1.90472	18
43	46030	2.17249	48163	2.07630	50331	1.98684	52538	1.90337	17
44	46065	2.17083	48198	2.07476	50368	1.98540	52575	1.90203	16
45	46101	2.16917	48234	2.07321	50404	1.98396	52613	1.90069	15
46	46136	2.16751	48270	2.07167	50441	1.98253	52650	1.89935	14
47	46171	2.16585	48306	2.07014	50477	1.98110	52687	1.89801	13
48	46206	2.16420	48342	2.06860	50514	1.97966	52724	1.89667	12
49	46242	2.16255	48378	2.06706	50550	1.97823	52761	1.89533	11
50	46277	2.16090	48414	2.06553	50587	1.97681	52798	1.89400	10
51	46312	2.15925	48450	2.06400	50623	1.97538	52836	1.89266	9
52	46348	2.15760	48486	2.06247	50660	1.97395	52873	1.89133	8
53	46383	2.15596	48521	2.06094	50696	1.97253	52910	1.89000	7
54	46418	2.15433	48557	2.05942	50733	1.97111	52947	1.88867	6
55	46454	2.15268	48593	2.05790	50769	1.96969	52985	1.88734	5
56	46489	2.15104	48629	2.05637	50806	1.96827	53022	1.88602	4
57	46525	2.14940	48665	2.05485	50843	1.96685	53059	1.88469	3
58	46560	2.14777	48701	2.05333	50879	1.96544	53096	1.88337	2
59	46595	2.14614	48737	2.05182	50916	1.96402	53134	1.88205	1
60	46631	2.14451	48773	2.05030	50953	1.96261	53171	1.88073	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	65°		64°		63°		62°		

TABLE XII.—TANGENTS AND COTANGENTS.

	28°		29°		30°		31°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	53171	1.88073	55431	1.80405	57735	1.73205	60086	1.66428	60
1	53208	1.87941	55469	1.80281	57774	1.73089	60126	1.66318	59
2	53246	1.87809	55507	1.80158	57818	1.72973	60165	1.66209	58
3	53283	1.87677	55545	1.80034	57851	1.72857	60205	1.66099	57
4	53320	1.87546	55583	1.79911	57890	1.72741	60245	1.65990	56
5	53358	1.87415	55621	1.79788	57929	1.72625	60284	1.65881	55
6	53395	1.87283	55659	1.79665	57968	1.72509	60324	1.65772	54
7	53432	1.87152	55697	1.79542	58007	1.72393	60364	1.65663	53
8	53470	1.87021	55736	1.79419	58046	1.72278	60403	1.65554	52
9	53507	1.86891	55774	1.79296	58085	1.72163	60443	1.65445	51
10	53545	1.86760	55812	1.79174	58124	1.72047	60483	1.65337	50
11	53582	1.86630	55850	1.79051	58162	1.71932	60522	1.65228	49
12	53620	1.86499	55888	1.78929	58201	1.71817	60562	1.65120	48
13	53657	1.86369	55926	1.78807	58240	1.71702	60602	1.65011	47
14	53694	1.86239	55964	1.78685	58279	1.71588	60642	1.64903	46
15	53732	1.86109	56003	1.78563	58318	1.71473	60681	1.64795	45
16	53769	1.85979	56041	1.78441	58357	1.71358	60721	1.64687	44
17	53807	1.85850	56079	1.78319	58396	1.71244	60761	1.64579	43
18	53844	1.85720	56117	1.78198	58435	1.71129	60801	1.64471	42
19	53882	1.85591	56156	1.78077	58474	1.71015	60841	1.64363	41
20	53920	1.85462	56194	1.77955	58513	1.70901	60881	1.64256	40
21	53957	1.85333	56232	1.77834	58552	1.70787	60921	1.64148	39
22	53995	1.85204	56270	1.77713	58591	1.70673	60960	1.64041	38
23	54032	1.85075	56309	1.77592	58631	1.70560	61000	1.63934	37
24	54070	1.84946	56347	1.77471	58670	1.70446	61040	1.63826	36
25	54107	1.84818	56385	1.77351	58709	1.70332	61080	1.63719	35
26	54145	1.84689	56424	1.77230	58748	1.70219	61120	1.63612	34
27	54183	1.84561	56462	1.77110	58787	1.70106	61160	1.63505	33
28	54220	1.84433	56501	1.76990	58826	1.69992	61200	1.63398	32
29	54258	1.84305	56539	1.76869	58865	1.69879	61240	1.63292	31
30	54296	1.84177	56577	1.76749	58905	1.69766	61280	1.63185	30
31	54333	1.84049	56616	1.76629	58944	1.69653	61320	1.63079	29
32	54371	1.83922	56654	1.76510	58983	1.69541	61360	1.62972	28
33	54409	1.83794	56693	1.76390	59022	1.69428	61400	1.62866	27
34	54446	1.83667	56731	1.76271	59061	1.69316	61440	1.62760	26
35	54484	1.83540	56769	1.76151	59101	1.69203	61480	1.62654	25
36	54522	1.83413	56808	1.76032	59140	1.69091	61520	1.62548	24
37	54560	1.83286	56846	1.75913	59179	1.68979	61561	1.62442	23
38	54597	1.83159	56885	1.75794	59218	1.68866	61601	1.62336	22
39	54635	1.83033	56923	1.75675	59258	1.68754	61641	1.62230	21
40	54673	1.82906	56962	1.75556	59297	1.68643	61681	1.62125	20
41	54711	1.82780	57000	1.75437	59336	1.68531	61721	1.62019	19
42	54748	1.82654	57039	1.75319	59376	1.68419	61761	1.61914	18
43	54786	1.82528	57078	1.75200	59415	1.68308	61801	1.61808	17
44	54824	1.82402	57116	1.75082	59454	1.68196	61842	1.61703	16
45	54862	1.82276	57155	1.74964	59494	1.68085	61882	1.61598	15
46	54900	1.82150	57193	1.74846	59533	1.67974	61922	1.61493	14
47	54938	1.82025	57232	1.74728	59573	1.67863	61962	1.61388	13
48	54975	1.81899	57271	1.74610	59612	1.67752	62003	1.61283	12
49	55013	1.81774	57309	1.74492	59651	1.67641	62043	1.61179	11
50	55051	1.81649	57348	1.74375	59691	1.67530	62083	1.61074	10
51	55089	1.81524	57386	1.74257	59730	1.67419	62124	1.60970	9
52	55127	1.81399	57425	1.74140	59770	1.67309	62164	1.60865	8
53	55165	1.81274	57464	1.74022	59809	1.67198	62204	1.60761	7
54	55203	1.81150	57503	1.73905	59849	1.67088	62245	1.60657	6
55	55241	1.81025	57541	1.73788	59888	1.66978	62285	1.60553	5
56	55279	1.80901	57580	1.73671	59928	1.66867	62325	1.60449	4
57	55317	1.80777	57619	1.73555	59967	1.66757	62366	1.60345	3
58	55355	1.80653	57657	1.73438	60007	1.66647	62406	1.60241	2
59	55393	1.80529	57696	1.73321	60046	1.66538	62446	1.60137	1
60	55431	1.80405	57735	1.73205	60086	1.66428	62487	1.60033	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	61°		60°		59°		58°		

TABLE XII.—TANGENTS AND COTANGENTS.

	32°		33°		34°		35°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	62487	1.60083	64941	1.53986	67451	1.48256	70021	1.42815	60
1	62527	1.59930	64982	1.53888	67493	1.48163	70064	1.42726	59
2	62568	1.59828	65024	1.53791	67536	1.48070	70107	1.42638	58
3	62608	1.59723	65065	1.53693	67578	1.47977	70151	1.42550	57
4	62649	1.59620	65106	1.53595	67620	1.47885	70194	1.42462	56
5	62689	1.59517	65148	1.53497	67663	1.47792	70238	1.42374	55
6	62730	1.59414	65189	1.53400	67705	1.47699	70281	1.42286	54
7	62770	1.59311	65231	1.53302	67748	1.47607	70325	1.42198	53
8	62811	1.59208	65272	1.53205	67790	1.47514	70368	1.42110	52
9	62852	1.59105	65314	1.53107	67832	1.47422	70412	1.42022	51
10	62892	1.59002	65355	1.53010	67875	1.47330	70455	1.41934	50
11	62933	1.58900	65397	1.52913	67917	1.47238	70499	1.41847	49
12	62973	1.58797	65438	1.52816	67960	1.47146	70542	1.41759	48
13	63014	1.58695	65480	1.52719	68002	1.47053	70586	1.41672	47
14	63055	1.58593	65521	1.52622	68045	1.46962	70629	1.41584	46
15	63095	1.58490	65563	1.52525	68088	1.46870	70673	1.41497	45
16	63136	1.58388	65604	1.52429	68130	1.46778	70717	1.41409	44
17	63177	1.58286	65646	1.52332	68173	1.46686	70760	1.41322	43
18	63217	1.58184	65688	1.52235	68215	1.46595	70804	1.41235	42
19	63258	1.58083	65729	1.52139	68258	1.46503	70848	1.41148	41
20	63299	1.57981	65771	1.52043	68301	1.46411	70891	1.41061	40
21	63340	1.57879	65813	1.51946	68343	1.46320	70935	1.40974	39
22	63380	1.57778	65854	1.51850	68386	1.46229	70979	1.40887	38
23	63421	1.57676	65896	1.51754	68429	1.46137	71023	1.40800	37
24	63462	1.57575	65938	1.51658	68471	1.46046	71066	1.40714	36
25	63503	1.57474	65980	1.51562	68514	1.45955	71110	1.40627	35
26	63544	1.57372	66021	1.51466	68557	1.45864	71154	1.40540	34
27	63584	1.57271	66063	1.51370	68600	1.45773	71198	1.40453	33
28	63625	1.57170	66105	1.51275	68642	1.45682	71242	1.40367	32
29	63666	1.57069	66147	1.51179	68685	1.45592	71285	1.40281	31
30	63707	1.56969	66189	1.51084	68728	1.45501	71329	1.40195	30
31	63748	1.56868	66230	1.50988	68771	1.45410	71373	1.40109	29
32	63789	1.56767	66272	1.50893	68814	1.45320	71417	1.40022	28
33	63830	1.56667	66314	1.50797	68857	1.45229	71461	1.39936	27
34	63871	1.56566	66356	1.50702	68900	1.45139	71505	1.39850	26
35	63912	1.56466	66398	1.50607	68942	1.45049	71549	1.39764	25
36	63953	1.56366	66440	1.50512	68985	1.44958	71593	1.39679	24
37	63994	1.56265	66482	1.50417	69028	1.44868	71637	1.39593	23
38	64035	1.56165	66524	1.50322	69071	1.44778	71681	1.39507	22
39	64076	1.56065	66566	1.50228	69114	1.44688	71725	1.39421	21
40	64117	1.55966	66608	1.50133	69157	1.44598	71769	1.39336	20
41	64158	1.55866	66650	1.50038	69200	1.44508	71813	1.39250	19
42	64199	1.55766	66692	1.49944	69243	1.44418	71857	1.39165	18
43	64240	1.55666	66734	1.49849	69286	1.44329	71901	1.39079	17
44	64281	1.55567	66776	1.49755	69329	1.44239	71946	1.38994	16
45	64322	1.55467	66818	1.49661	69372	1.44149	71990	1.38909	15
46	64363	1.55368	66860	1.49566	69416	1.44060	72034	1.38824	14
47	64404	1.55269	66902	1.49472	69459	1.43970	72078	1.38738	13
48	64446	1.55170	66944	1.49378	69502	1.43881	72122	1.38653	12
49	64487	1.55071	66986	1.49284	69545	1.43792	72167	1.38568	11
50	64528	1.54973	67028	1.49190	69588	1.43703	72211	1.38484	10
51	64569	1.54873	67071	1.49097	69631	1.43614	72255	1.38399	9
52	64610	1.54774	67113	1.49003	69675	1.43525	72299	1.38314	8
53	64652	1.54675	67155	1.48909	69718	1.43436	72344	1.38229	7
54	64693	1.54576	67197	1.48816	69761	1.43347	72388	1.38145	6
55	64734	1.54478	67239	1.48722	69804	1.43258	72433	1.38060	5
56	64775	1.54379	67282	1.48629	69847	1.43169	72477	1.37976	4
57	64817	1.54281	67324	1.48536	69891	1.43080	72521	1.37891	3
58	64858	1.54183	67366	1.48442	69934	1.42992	72565	1.37807	2
59	64899	1.54085	67409	1.48349	69977	1.42903	72610	1.37722	1
60	64941	1.53986	67451	1.48256	70021	1.42815	72654	1.37638	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	57°		56°		55°		54°		

TABLE XII.—TANGENTS AND COTANGENTS.

	36°		37°		38°		39°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	72654	1.37638	75355	1.32704	78129	1.27994	80978	1.23490	60
1	72699	1.37554	75401	1.32624	78175	1.27917	81027	1.23416	59
2	72743	1.37470	75447	1.32544	78222	1.27841	81075	1.23343	58
3	72788	1.37386	75492	1.32464	78269	1.27764	81123	1.23270	57
4	72832	1.37302	75538	1.32384	78316	1.27688	81171	1.23196	56
5	72877	1.37218	75584	1.32304	78363	1.27611	81220	1.23123	55
6	72921	1.37134	75629	1.32224	78410	1.27535	81268	1.23050	54
7	72966	1.37050	75675	1.32144	78457	1.27458	81316	1.22977	53
8	73010	1.36967	75721	1.32064	78504	1.27382	81364	1.22904	52
9	73055	1.36883	75767	1.31984	78551	1.27306	81413	1.22831	51
10	73100	1.36800	75812	1.31904	78598	1.27230	81461	1.22758	50
11	73144	1.36716	75858	1.31825	78645	1.27153	81510	1.22685	49
12	73189	1.36633	75904	1.31745	78692	1.27077	81558	1.22612	48
13	73234	1.36549	75950	1.31666	78739	1.27001	81606	1.22539	47
14	73278	1.36466	75996	1.31586	78786	1.26925	81655	1.22467	46
15	73323	1.36383	76042	1.31507	78834	1.26849	81703	1.22394	45
16	73368	1.36300	76088	1.31427	78881	1.26774	81752	1.22321	44
17	73413	1.36217	76134	1.31348	78928	1.26698	81800	1.22249	43
18	73457	1.36134	76180	1.31269	78975	1.26622	81849	1.22176	42
19	73502	1.36051	76226	1.31190	79022	1.26546	81898	1.22104	41
20	73547	1.35968	76272	1.31110	79070	1.26471	81946	1.22031	40
21	73592	1.35885	76318	1.31031	79117	1.26395	81995	1.21959	39
22	73637	1.35802	76364	1.30952	79164	1.26319	82044	1.21886	38
23	73681	1.35719	76410	1.30873	79212	1.26244	82092	1.21814	37
24	73726	1.35637	76456	1.30795	79259	1.26169	82141	1.21743	36
25	73771	1.35554	76502	1.30716	79306	1.26093	82190	1.21670	35
26	73816	1.35472	76548	1.30637	79354	1.26018	82238	1.21598	34
27	73861	1.35389	76594	1.30558	79401	1.25943	82287	1.21526	33
28	73906	1.35307	76640	1.30480	79449	1.25867	82336	1.21454	32
29	73951	1.35224	76686	1.30401	79496	1.25792	82385	1.21382	31
30	73996	1.35142	76733	1.30323	79544	1.25717	82434	1.21310	30
31	74041	1.35060	76779	1.30244	79591	1.25642	82483	1.21238	29
32	74086	1.34978	76825	1.30166	79639	1.25567	82531	1.21166	28
33	74131	1.34896	76871	1.30087	79686	1.25492	82580	1.21094	27
34	74176	1.34814	76918	1.30009	79734	1.25417	82629	1.21022	26
35	74221	1.34732	76964	1.29931	79781	1.25343	82678	1.20951	25
36	74267	1.34650	77010	1.29853	79829	1.25268	82727	1.20879	24
37	74312	1.34568	77057	1.29775	79877	1.25193	82776	1.20808	23
38	74357	1.34487	77103	1.29696	79924	1.25118	82825	1.20736	22
39	74402	1.34405	77149	1.29618	79972	1.25044	82874	1.20665	21
40	74447	1.34323	77196	1.29541	80020	1.24969	82923	1.20593	20
41	74492	1.34242	77242	1.29463	80067	1.24895	82972	1.20522	19
42	74538	1.34160	77289	1.29385	80115	1.24820	83022	1.20451	18
43	74583	1.34079	77335	1.29307	80163	1.24746	83071	1.20379	17
44	74628	1.33998	77382	1.29229	80211	1.24672	83120	1.20308	16
45	74674	1.33916	77428	1.29152	80258	1.24597	83169	1.20237	15
46	74719	1.33835	77475	1.29074	80306	1.24523	83218	1.20166	14
47	74764	1.33754	77521	1.28997	80354	1.24449	83268	1.20095	13
48	74810	1.33673	77568	1.28919	80402	1.24375	83317	1.20024	12
49	74855	1.33592	77615	1.28842	80450	1.24301	83366	1.19953	11
50	74900	1.33511	77661	1.28764	80498	1.24227	83415	1.19882	10
51	74946	1.33430	77708	1.28687	80546	1.24153	83465	1.19811	9
52	74991	1.33349	77754	1.28610	80594	1.24079	83514	1.19740	8
53	75037	1.33268	77801	1.28533	80642	1.24005	83564	1.19669	7
54	75082	1.33187	77848	1.28456	80690	1.23931	83613	1.19598	6
55	75128	1.33107	77895	1.28379	80738	1.23858	83662	1.19528	5
56	75173	1.33026	77941	1.28302	80786	1.23784	83712	1.19457	4
57	75219	1.32946	77988	1.28225	80834	1.23710	83761	1.19387	3
58	75264	1.32865	78035	1.28148	80882	1.23637	83811	1.19316	2
59	75310	1.32785	78082	1.28071	80930	1.23563	83860	1.19246	1
60	75355	1.32704	78129	1.27994	80978	1.23490	83910	1.19175	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	53°		52°		51°		50°		

TABLE XII.—TANGENTS AND COTANGENTS.

	40°		41°		42°		43°		
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	83910	1.19175	86929	1.15087	90040	1.11061	93252	1.07237	60
1	83960	1.19105	86980	1.14969	90093	1.10996	93306	1.07174	59
2	84009	1.19035	87031	1.14902	90146	1.10931	93360	1.07112	58
3	84059	1.18964	87082	1.14834	90199	1.10867	93415	1.07049	57
4	84108	1.18894	87133	1.14767	90251	1.10802	93469	1.06987	56
5	84158	1.18824	87184	1.14699	90304	1.10737	93524	1.06925	55
6	84208	1.18754	87236	1.14632	90357	1.10672	93578	1.06862	54
7	84258	1.18684	87287	1.14565	90410	1.10607	93633	1.06800	53
8	84307	1.18614	87338	1.14498	90463	1.10543	93688	1.06738	52
9	84357	1.18544	87389	1.14430	90516	1.10478	93742	1.06676	51
10	84407	1.18474	87441	1.14363	90569	1.10414	93797	1.06613	50
11	84457	1.18404	87492	1.14296	90621	1.10349	93852	1.06551	49
12	84507	1.18334	87543	1.14229	90674	1.10285	93906	1.06489	48
13	84556	1.18264	87595	1.14162	90727	1.10220	93961	1.06427	47
14	84606	1.18194	87646	1.14095	90781	1.10156	94016	1.06365	46
15	84656	1.18125	87698	1.14028	90834	1.10091	94071	1.06303	45
16	84706	1.18055	87749	1.13961	90887	1.10027	94125	1.06241	44
17	84756	1.17986	87801	1.13894	90940	1.09963	94180	1.06179	43
18	84806	1.17916	87852	1.13828	90993	1.09899	94235	1.06117	42
19	84856	1.17846	87904	1.13761	91046	1.09834	94290	1.06056	41
20	84906	1.17777	87955	1.13694	91099	1.09770	94345	1.05994	40
21	84956	1.17708	88007	1.13627	91153	1.09706	94400	1.05932	39
22	85006	1.17638	88059	1.13561	91206	1.09642	94455	1.05870	38
23	85057	1.17569	88110	1.13494	91259	1.09578	94510	1.05809	37
24	85107	1.17500	88162	1.13428	91313	1.09514	94565	1.05747	36
25	85157	1.17430	88214	1.13361	91366	1.09450	94620	1.05685	35
26	85207	1.17361	88265	1.13295	91419	1.09386	94676	1.05624	34
27	85257	1.17292	88317	1.13229	91473	1.09322	94731	1.05562	33
28	85308	1.17223	88369	1.13162	91526	1.09258	94786	1.05501	32
29	85358	1.17154	88421	1.13096	91580	1.09195	94841	1.05439	31
30	85408	1.17085	88473	1.13029	91633	1.09131	94896	1.05378	30
31	85458	1.17016	88524	1.12963	91687	1.09067	94952	1.05317	29
32	85509	1.16947	88576	1.12897	91740	1.09003	95007	1.05255	28
33	85559	1.16878	88628	1.12831	91794	1.08940	95062	1.05194	27
34	85609	1.16809	88680	1.12765	91847	1.08876	95118	1.05133	26
35	85660	1.16741	88732	1.12699	91901	1.08813	95173	1.05072	25
36	85710	1.16672	88784	1.12633	91955	1.08749	95229	1.05010	24
37	85761	1.16603	88836	1.12567	92008	1.08686	95284	1.04949	23
38	85811	1.16535	88888	1.12501	92062	1.08622	95340	1.04888	22
39	85862	1.16466	88940	1.12435	92116	1.08559	95395	1.04827	21
40	85912	1.16398	88992	1.12369	92170	1.08496	95451	1.04766	20
41	85963	1.16329	89045	1.12303	92224	1.08432	95506	1.04705	19
42	86014	1.16261	89097	1.12238	92277	1.08369	95562	1.04644	18
43	86064	1.16192	89149	1.12172	92331	1.08306	95618	1.04583	17
44	86115	1.16124	89201	1.12106	92385	1.08243	95673	1.04522	16
45	86166	1.16056	89253	1.12041	92439	1.08179	95729	1.04461	15
46	86216	1.15987	89306	1.11975	92493	1.08116	95785	1.04401	14
47	86267	1.15919	89358	1.11909	92547	1.08053	95841	1.04340	13
48	86318	1.15851	89410	1.11844	92601	1.07990	95897	1.04279	12
49	86368	1.15783	89463	1.11778	92655	1.07927	95952	1.04218	11
50	86419	1.15715	89515	1.11713	92709	1.07864	96008	1.04158	10
51	86470	1.15647	89567	1.11648	92763	1.07801	96064	1.04097	9
52	86521	1.15579	89620	1.11582	92817	1.07738	96120	1.04036	8
53	86572	1.15511	89672	1.11517	92872	1.07676	96176	1.03976	7
54	86623	1.15443	89725	1.11452	92926	1.07613	96232	1.03915	6
55	86674	1.15375	89777	1.11387	92980	1.07550	96288	1.03855	5
56	86725	1.15308	89830	1.11321	93034	1.07487	96344	1.03794	4
57	86776	1.15240	89883	1.11256	93088	1.07425	96400	1.03734	3
58	86827	1.15172	89935	1.11191	93143	1.07362	96457	1.03674	2
59	86878	1.15104	89988	1.11126	93197	1.07299	96513	1.03613	1
60	86929	1.15037	90040	1.11061	93252	1.07237	96569	1.03553	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	49°		48°		47°		46°		

TABLE XII.—TANGENTS AND COTANGENTS.

44°						44°						44°					
	Tang	Cotang					Tang	Cotang					Tang	Cotang			
0	96569	1.03553	60	20	97700	1.02355	40	40	98843	1.01170	20						
1	96625	1.03493	59	21	97756	1.02295	39	41	98901	1.01112	19						
2	96681	1.03433	58	22	97813	1.02236	38	42	98958	1.01053	18						
3	96738	1.03372	57	23	97870	1.02176	37	43	99016	1.00994	17						
4	96794	1.03312	56	24	97927	1.02117	36	44	99073	1.00935	16						
5	96850	1.03252	55	25	97984	1.02057	35	45	99131	1.00876	15						
6	96907	1.03192	54	26	98041	1.01998	34	46	99189	1.00818	14						
7	96963	1.03132	53	27	98098	1.01939	33	47	99247	1.00759	13						
8	97020	1.03072	52	28	98155	1.01879	32	48	99304	1.00701	12						
9	97076	1.03012	51	29	98213	1.01820	31	49	99362	1.00642	11						
10	97133	1.02952	50	30	98270	1.01761	30	50	99420	1.00583	10						
11	97189	1.02892	49	31	98327	1.01702	29	51	99478	1.00525	9						
12	97246	1.02832	48	32	98384	1.01642	28	52	99536	1.00467	8						
13	97302	1.02772	47	33	98441	1.01583	27	53	99594	1.00408	7						
14	97359	1.02713	46	34	98499	1.01524	26	54	99652	1.00350	6						
15	97416	1.02653	45	35	98556	1.01465	25	55	99710	1.00291	5						
16	97472	1.02593	44	36	98613	1.01406	24	56	99768	1.00233	4						
17	97529	1.02533	43	37	98671	1.01347	23	57	99826	1.00175	3						
18	97586	1.02474	42	38	98728	1.01288	22	58	99884	1.00116	2						
19	97643	1.02414	41	39	98786	1.01229	21	59	99942	1.00058	1						
20	97700	1.02355	40	40	98843	1.01170	20	60	1.00000	1.00000	0						
	Cotang	Tang					Cotang	Tang					Cotang	Tang			
45°																	
45°																	

TABLE XIII.—VERSINES AND EXSECANTS.

	0°		1°		2°		3°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.00000	.00000	.00015	.00015	.00061	.00061	.00137	.00137	0
1	.00000	.00000	.00016	.00016	.00062	.00062	.00139	.00139	1
2	.00000	.00000	.00016	.00016	.00063	.00063	.00140	.00140	2
3	.00000	.00000	.00017	.00017	.00064	.00064	.00142	.00142	3
4	.00000	.00000	.00017	.00017	.00065	.00065	.00143	.00143	4
5	.00000	.00000	.00018	.00018	.00066	.00066	.00145	.00145	5
6	.00000	.00000	.00018	.00018	.00067	.00067	.00146	.00146	6
7	.00000	.00000	.00019	.00019	.00068	.00068	.00148	.00148	7
8	.00000	.00000	.00020	.00020	.00069	.00069	.00150	.00150	8
9	.00000	.00000	.00020	.00020	.00070	.00070	.00151	.00151	9
10	.00000	.00000	.00021	.00021	.00071	.00072	.00153	.00153	10
11	.00001	.00001	.00021	.00021	.00073	.00073	.00154	.00155	11
12	.00001	.00001	.00022	.00022	.00074	.00074	.00156	.00156	12
13	.00001	.00001	.00023	.00023	.00075	.00075	.00158	.00158	13
14	.00001	.00001	.00023	.00023	.00076	.00076	.00159	.00159	14
15	.00001	.00001	.00024	.00024	.00077	.00077	.00161	.00161	15
16	.00001	.00001	.00024	.00024	.00078	.00078	.00162	.00163	16
17	.00001	.00001	.00025	.00025	.00079	.00079	.00164	.00164	17
18	.00001	.00001	.00026	.00026	.00081	.00081	.00166	.00166	18
19	.00002	.00002	.00026	.00026	.00082	.00082	.00168	.00168	19
20	.00002	.00002	.00027	.00027	.00083	.00083	.00169	.00169	20
21	.00002	.00002	.00028	.00028	.00084	.00084	.00171	.00171	21
22	.00002	.00002	.00028	.00028	.00085	.00085	.00173	.00173	22
23	.00002	.00002	.00029	.00029	.00087	.00087	.00174	.00175	23
24	.00002	.00002	.00030	.00030	.00088	.00088	.00176	.00176	24
25	.00003	.00003	.00031	.00031	.00089	.00089	.00178	.00178	25
26	.00003	.00003	.00031	.00031	.00090	.00090	.00179	.00180	26
27	.00003	.00003	.00032	.00032	.00091	.00091	.00181	.00182	27
28	.00003	.00003	.00033	.00033	.00093	.00093	.00183	.00183	28
29	.00004	.00004	.00034	.00034	.00094	.00094	.00185	.00185	29
30	.00004	.00004	.00034	.00034	.00095	.00095	.00187	.00187	30
31	.00004	.00004	.00035	.00035	.00096	.00097	.00188	.00189	31
32	.00004	.00004	.00036	.00036	.00098	.00098	.00190	.00190	32
33	.00005	.00005	.00037	.00037	.00099	.00099	.00192	.00192	33
34	.00005	.00005	.00037	.00037	.00100	.00100	.00194	.00194	34
35	.00005	.00005	.00038	.00038	.00102	.00102	.00196	.00196	35
36	.00005	.00005	.00039	.00039	.00103	.00103	.00197	.00198	36
37	.00006	.00006	.00040	.00040	.00104	.00104	.00199	.00200	37
38	.00006	.00006	.00041	.00041	.00106	.00106	.00201	.00201	38
39	.00006	.00006	.00041	.00041	.00107	.00107	.00203	.00203	39
40	.00007	.00007	.00042	.00042	.00108	.00108	.00205	.00205	40
41	.00007	.00007	.00043	.00043	.00110	.00110	.00207	.00207	41
42	.00007	.00007	.00044	.00044	.00111	.00111	.00208	.00209	42
43	.00008	.00008	.00045	.00045	.00112	.00113	.00210	.00211	43
44	.00008	.00008	.00046	.00046	.00114	.00114	.00212	.00213	44
45	.00009	.00009	.00047	.00047	.00115	.00115	.00214	.00215	45
46	.00009	.00009	.00048	.00048	.00117	.00117	.00216	.00216	46
47	.00009	.00009	.00048	.00048	.00118	.00118	.00218	.00218	47
48	.00010	.00010	.00049	.00049	.00119	.00120	.00220	.00220	48
49	.00010	.00010	.00050	.00050	.00121	.00121	.00222	.00222	49
50	.00011	.00011	.00051	.00051	.00122	.00122	.00224	.00224	50
51	.00011	.00011	.00052	.00052	.00124	.00124	.00226	.00226	51
52	.00011	.00011	.00053	.00053	.00125	.00125	.00228	.00228	52
53	.00012	.00012	.00054	.00054	.00127	.00127	.00230	.00230	53
54	.00012	.00012	.00055	.00055	.00128	.00128	.00232	.00232	54
55	.00013	.00013	.00056	.00056	.00130	.00130	.00234	.00234	55
56	.00013	.00013	.00057	.00057	.00131	.00131	.00236	.00236	56
57	.00014	.00014	.00058	.00058	.00133	.00133	.00238	.00238	57
58	.00014	.00014	.00059	.00059	.00134	.00134	.00240	.00240	58
59	.00015	.00015	.00060	.00060	.00136	.00136	.00242	.00242	59
60	.00015	.00015	.00061	.00061	.00137	.00137	.00244	.00244	60

TABLE XIII.—VERSINES AND EXSECANTS.

	4°		5°		6°		7°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.00244	.00244	.00881	.00882	.00548	.00551	.00745	.00751	0
1	.00246	.00246	.00883	.00885	.00551	.00554	.00749	.00755	1
2	.00248	.00248	.00886	.00887	.00554	.00557	.00752	.00758	2
3	.00250	.00250	.00888	.00890	.00557	.00560	.00756	.00762	3
4	.00252	.00252	.00891	.00892	.00560	.00563	.00760	.00765	4
5	.00254	.00254	.00893	.00895	.00563	.00566	.00763	.00769	5
6	.00256	.00257	.00896	.00897	.00566	.00569	.00767	.00773	6
7	.00258	.00259	.00898	.00900	.00569	.00573	.00770	.00776	7
8	.00260	.00261	.00901	.00903	.00572	.00576	.00774	.00780	8
9	.00262	.00263	.00904	.00905	.00576	.00579	.00778	.00784	9
10	.00264	.00265	.00906	.00908	.00579	.00582	.00781	.00787	10
11	.00266	.00267	.00909	.00911	.00582	.00585	.00785	.00791	11
12	.00269	.00269	.00912	.00913	.00585	.00588	.00789	.00795	12
13	.00271	.00271	.00914	.00916	.00588	.00592	.00792	.00799	13
14	.00273	.00274	.00917	.00919	.00591	.00595	.00796	.00802	14
15	.00275	.00276	.00920	.00921	.00594	.00598	.00800	.00806	15
16	.00277	.00278	.00922	.00924	.00598	.00601	.00803	.00810	16
17	.00279	.00280	.00925	.00927	.00601	.00604	.00807	.00813	17
18	.00281	.00282	.00928	.00929	.00604	.00608	.00811	.00817	18
19	.00284	.00284	.00930	.00932	.00607	.00611	.00814	.00821	19
20	.00286	.00287	.00933	.00935	.00610	.00614	.00818	.00825	20
21	.00288	.00289	.00936	.00938	.00614	.00617	.00822	.00828	21
22	.00290	.00291	.00938	.00940	.00617	.00621	.00825	.00832	22
23	.00293	.00293	.00941	.00943	.00620	.00624	.00829	.00836	23
24	.00295	.00296	.00944	.00946	.00623	.00627	.00833	.00840	24
25	.00297	.00298	.00947	.00949	.00626	.00630	.00837	.00844	25
26	.00299	.00300	.00949	.00951	.00630	.00634	.00840	.00848	26
27	.00301	.00302	.00952	.00954	.00633	.00637	.00844	.00851	27
28	.00304	.00305	.00955	.00957	.00636	.00640	.00848	.00855	28
29	.00306	.00307	.00958	.00960	.00640	.00644	.00852	.00859	29
30	.00308	.00309	.00960	.00963	.00643	.00647	.00856	.00863	30
31	.00311	.00312	.00963	.00965	.00646	.00650	.00859	.00867	31
32	.00313	.00314	.00966	.00968	.00649	.00654	.00863	.00871	32
33	.00315	.00316	.00969	.00971	.00653	.00657	.00867	.00875	33
34	.00317	.00318	.00972	.00974	.00656	.00660	.00871	.00878	34
35	.00320	.00321	.00974	.00977	.00659	.00664	.00875	.00882	35
36	.00322	.00323	.00977	.00980	.00663	.00667	.00878	.00886	36
37	.00324	.00326	.00980	.00982	.00666	.00671	.00882	.00890	37
38	.00327	.00328	.00983	.00985	.00669	.00674	.00886	.00894	38
39	.00329	.00330	.00986	.00988	.00673	.00677	.00890	.00898	39
40	.00332	.00333	.00989	.00991	.00676	.00681	.00894	.00902	40
41	.00334	.00335	.00992	.00994	.00680	.00684	.00898	.00906	41
42	.00336	.00337	.00994	.00997	.00683	.00688	.00902	.00910	42
43	.00339	.00340	.00997	.00500	.00686	.00691	.00906	.00914	43
44	.00341	.00342	.00500	.00503	.00690	.00695	.00909	.00918	44
45	.00343	.00345	.00503	.00506	.00693	.00698	.00913	.00922	45
46	.00346	.00347	.00506	.00509	.00697	.00701	.00917	.00926	46
47	.00348	.00350	.00509	.00512	.00700	.00705	.00921	.00930	47
48	.00351	.00352	.00512	.00515	.00703	.00708	.00925	.00934	48
49	.00353	.00354	.00515	.00518	.00707	.00712	.00929	.00938	49
50	.00356	.00357	.00518	.00521	.00710	.00715	.00933	.00942	50
51	.00358	.00359	.00521	.00524	.00714	.00719	.00937	.00946	51
52	.00361	.00362	.00524	.00527	.00717	.00722	.00941	.00950	52
53	.00363	.00364	.00527	.00530	.00721	.00726	.00945	.00954	53
54	.00365	.00367	.00530	.00533	.00724	.00730	.00949	.00958	54
55	.00368	.00369	.00533	.00536	.00728	.00733	.00953	.00962	55
56	.00370	.00372	.00536	.00539	.00731	.00737	.00957	.00966	56
57	.00373	.00374	.00539	.00542	.00735	.00740	.00961	.00970	57
58	.00375	.00377	.00542	.00545	.00738	.00744	.00965	.00975	58
59	.00378	.00379	.00545	.00548	.00742	.00747	.00969	.00979	59
60	.00381	.00382	.00548	.00551	.00745	.00751	.00973	.00983	60

TABLE XIII.—VERSINES AND EXSECANTS.

	8°		9°		10°		11°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.00973	.00983	.01281	.01247	.01519	.01543	.01837	.01873	0
1	.00977	.00987	.01286	.01251	.01524	.01548	.01843	.01877	1
2	.00981	.00991	.01240	.01256	.01529	.01553	.01848	.01883	2
3	.00985	.00995	.01245	.01261	.01534	.01558	.01854	.01889	3
4	.00989	.00999	.01249	.01265	.01540	.01564	.01860	.01895	4
5	.00994	.01004	.01254	.01270	.01545	.01569	.01865	.01901	5
6	.00998	.01008	.01259	.01275	.01550	.01574	.01871	.01906	6
7	.01002	.01012	.01263	.01279	.01555	.01579	.01876	.01912	7
8	.01006	.01016	.01268	.01284	.01560	.01585	.01882	.01918	8
9	.01010	.01020	.01273	.01289	.01565	.01590	.01888	.01924	9
10	.01014	.01024	.01277	.01294	.01570	.01595	.01893	.01930	10
11	.01018	.01029	.01282	.01298	.01575	.01601	.01899	.01936	11
12	.01022	.01033	.01286	.01303	.01580	.01606	.01904	.01941	12
13	.01027	.01037	.01291	.01308	.01586	.01611	.01910	.01947	13
14	.01031	.01041	.01296	.01313	.01591	.01616	.01916	.01953	14
15	.01035	.01046	.01300	.01318	.01596	.01622	.01921	.01959	15
16	.01039	.01050	.01305	.01323	.01601	.01627	.01927	.01965	16
17	.01043	.01054	.01310	.01327	.01606	.01633	.01933	.01971	17
18	.01047	.01059	.01314	.01332	.01612	.01638	.01939	.01977	18
19	.01052	.01063	.01319	.01337	.01617	.01643	.01944	.01983	19
20	.01056	.01067	.01324	.01342	.01622	.01649	.01950	.01989	20
21	.01060	.01071	.01329	.01346	.01627	.01654	.01956	.01995	21
22	.01064	.01076	.01333	.01351	.01632	.01659	.01961	.02001	22
23	.01069	.01080	.01338	.01356	.01638	.01665	.01967	.02007	23
24	.01073	.01084	.01343	.01361	.01643	.01670	.01973	.02013	24
25	.01077	.01089	.01348	.01366	.01648	.01676	.01979	.02019	25
26	.01081	.01093	.01353	.01371	.01653	.01681	.01984	.02025	26
27	.01086	.01097	.01357	.01376	.01659	.01687	.01990	.02031	27
28	.01090	.01102	.01363	.01381	.01664	.01692	.01996	.02037	28
29	.01094	.01106	.01367	.01386	.01669	.01698	.02002	.02043	29
30	.01098	.01111	.01371	.01391	.01675	.01703	.02008	.02049	30
31	.01103	.01115	.01376	.01395	.01680	.01709	.02013	.02055	31
32	.01107	.01119	.01381	.01400	.01685	.01714	.02019	.02061	32
33	.01111	.01124	.01386	.01405	.01690	.01720	.02025	.02067	33
34	.01116	.01128	.01391	.01410	.01696	.01725	.02031	.02073	34
35	.01120	.01133	.01396	.01415	.01701	.01731	.02037	.02079	35
36	.01124	.01137	.01400	.01420	.01706	.01736	.02042	.02085	36
37	.01129	.01142	.01405	.01425	.01712	.01742	.02048	.02091	37
38	.01133	.01146	.01410	.01430	.01717	.01747	.02054	.02097	38
39	.01137	.01151	.01415	.01435	.01723	.01753	.02060	.02103	39
40	.01142	.01155	.01420	.01440	.01728	.01758	.02066	.02110	40
41	.01146	.01160	.01425	.01445	.01733	.01764	.02072	.02116	41
42	.01151	.01164	.01430	.01450	.01739	.01769	.02078	.02122	42
43	.01155	.01169	.01435	.01455	.01744	.01775	.02084	.02128	43
44	.01159	.01173	.01439	.01461	.01750	.01781	.02090	.02134	44
45	.01164	.01178	.01444	.01466	.01755	.01786	.02095	.02140	45
46	.01168	.01182	.01449	.01471	.01760	.01792	.02101	.02146	46
47	.01173	.01187	.01454	.01476	.01766	.01798	.02107	.02153	47
48	.01177	.01191	.01459	.01481	.01771	.01803	.02113	.02159	48
49	.01182	.01196	.01464	.01486	.01777	.01809	.02119	.02165	49
50	.01186	.01200	.01469	.01491	.01782	.01815	.02125	.02171	50
51	.01191	.01205	.01474	.01496	.01788	.01820	.02131	.02178	51
52	.01195	.01209	.01479	.01501	.01793	.01826	.02137	.02184	52
53	.01200	.01214	.01484	.01506	.01799	.01832	.02143	.02190	53
54	.01204	.01219	.01489	.01512	.01804	.01837	.02149	.02196	54
55	.01209	.01223	.01494	.01517	.01810	.01843	.02155	.02203	55
56	.01213	.01228	.01499	.01522	.01815	.01849	.02161	.02209	56
57	.01218	.01233	.01504	.01527	.01821	.01854	.02167	.02215	57
58	.01222	.01237	.01509	.01532	.01826	.01860	.02173	.02221	58
59	.01227	.01242	.01514	.01537	.01832	.01866	.02179	.02228	59
60	.01231	.01247	.01519	.01543	.01837	.01872	.02185	.02234	60

TABLE XIII.—VERSINES AND EXSECANTS.

	12°		13°		14°		15°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.02185	.02234	.02563	.02630	.02970	.03061	.03407	.03528	0
1	.02191	.02240	.02570	.02637	.02977	.03069	.03415	.03536	1
2	.02197	.02247	.02576	.02644	.02985	.03076	.03422	.03544	2
3	.02203	.02253	.02583	.02651	.02992	.03084	.03430	.03552	3
4	.02210	.02259	.02589	.02658	.02999	.03091	.03438	.03560	4
5	.02216	.02266	.02596	.02665	.03006	.03099	.03445	.03568	5
6	.02222	.02273	.02602	.02672	.03013	.03106	.03453	.03576	6
7	.02228	.02279	.02609	.02679	.03020	.03114	.03460	.03584	7
8	.02234	.02285	.02616	.02686	.03027	.03121	.03468	.03592	8
9	.02240	.02291	.02622	.02693	.03034	.03129	.03476	.03601	9
10	.02246	.02296	.02629	.02700	.03041	.03137	.03483	.03609	10
11	.02252	.02304	.02635	.02707	.03048	.03144	.03491	.03617	11
12	.02258	.02311	.02642	.02714	.03055	.03152	.03498	.03625	12
13	.02265	.02317	.02649	.02721	.03063	.03159	.03506	.03633	13
14	.02271	.02323	.02655	.02728	.03070	.03167	.03514	.03642	14
15	.02277	.02330	.02662	.02735	.03077	.03175	.03521	.03650	15
16	.02283	.02336	.02669	.02742	.03084	.03182	.03529	.03658	16
17	.02289	.02343	.02675	.02749	.03091	.03190	.03537	.03666	17
18	.02295	.02349	.02682	.02756	.03098	.03198	.03544	.03674	18
19	.02302	.02356	.02689	.02763	.03106	.03205	.03552	.03682	19
20	.02308	.02363	.02696	.02770	.03113	.03213	.03560	.03691	20
21	.02314	.02369	.02702	.02777	.03120	.03221	.03567	.03699	21
22	.02320	.02375	.02709	.02784	.03127	.03228	.03575	.03708	22
23	.02327	.02382	.02716	.02791	.03134	.03236	.03583	.03716	23
24	.02333	.02388	.02722	.02799	.03142	.03244	.03590	.03724	24
25	.02339	.02395	.02729	.02806	.03149	.03251	.03598	.03732	25
26	.02345	.02402	.02736	.02813	.03156	.03259	.03606	.03741	26
27	.02352	.02408	.02743	.02820	.03163	.03267	.03614	.03749	27
28	.02358	.02415	.02749	.02827	.03171	.03275	.03621	.03758	28
29	.02364	.02421	.02756	.02834	.03178	.03282	.03629	.03766	29
30	.02370	.02428	.02763	.02842	.03185	.03290	.03637	.03774	30
31	.02377	.02435	.02770	.02849	.03193	.03298	.03645	.03783	31
32	.02383	.02441	.02777	.02856	.03200	.03306	.03653	.03791	32
33	.02389	.02448	.02783	.02863	.03207	.03313	.03660	.03799	33
34	.02396	.02454	.02790	.02870	.03214	.03321	.03668	.03808	34
35	.02402	.02461	.02797	.02878	.03222	.03329	.03676	.03816	35
36	.02408	.02468	.02804	.02885	.03229	.03337	.03684	.03825	36
37	.02415	.02474	.02811	.02892	.03236	.03345	.03692	.03833	37
38	.02421	.02481	.02818	.02899	.03244	.03353	.03699	.03842	38
39	.02427	.02488	.02824	.02907	.03251	.03360	.03707	.03850	39
40	.02434	.02494	.02831	.02914	.03258	.03368	.03715	.03858	40
41	.02440	.02501	.02838	.02921	.03266	.03376	.03723	.03867	41
42	.02447	.02508	.02845	.02928	.03273	.03384	.03731	.03875	42
43	.02453	.02515	.02852	.02936	.03281	.03392	.03739	.03884	43
44	.02459	.02522	.02859	.02943	.03288	.03400	.03747	.03892	44
45	.02466	.02528	.02866	.02950	.03295	.03408	.03754	.03901	45
46	.02473	.02535	.02873	.02958	.03303	.03416	.03762	.03909	46
47	.02479	.02542	.02880	.02965	.03310	.03424	.03770	.03918	47
48	.02485	.02548	.02887	.02972	.03318	.03432	.03778	.03927	48
49	.02492	.02555	.02894	.02980	.03325	.03439	.03786	.03935	49
50	.02498	.02562	.02900	.02987	.03333	.03447	.03794	.03944	50
51	.02504	.02569	.02907	.02994	.03340	.03455	.03802	.03952	51
52	.02511	.02576	.02914	.03002	.03347	.03463	.03810	.03961	52
53	.02517	.02582	.02921	.03009	.03355	.03471	.03818	.03969	53
54	.02524	.02589	.02928	.03017	.03362	.03479	.03826	.03978	54
55	.02530	.02596	.02935	.03024	.03370	.03487	.03834	.03987	55
56	.02537	.02603	.02942	.03032	.03377	.03495	.03842	.03995	56
57	.02543	.02610	.02949	.03039	.03385	.03503	.03850	.04004	57
58	.02550	.02617	.02956	.03046	.03392	.03512	.03858	.04013	58
59	.02556	.02624	.02963	.03054	.03400	.03520	.03866	.04021	59
60	.02563	.02630	.02970	.03061	.03407	.03528	.03874	.04030	60

TABLE XIII.—VERSINES AND EXSECANTS.

	16°		17°		18°		19°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.03874	.04030	.04370	.04569	.04894	.05146	.05448	.05762	0
1	.03882	.04039	.04378	.04578	.04908	.05156	.05458	.05773	1
2	.03890	.04047	.04387	.04588	.04912	.05166	.05467	.05783	2
3	.03898	.04056	.04395	.04597	.04921	.05176	.05477	.05794	3
4	.03906	.04065	.04404	.04606	.04930	.05186	.05486	.05805	4
5	.03914	.04073	.04412	.04616	.04939	.05196	.05496	.05815	5
6	.03922	.04082	.04421	.04625	.04948	.05206	.05505	.05826	6
7	.03930	.04091	.04429	.04635	.04957	.05216	.05515	.05836	7
8	.03938	.04100	.04438	.04644	.04967	.05226	.05524	.05847	8
9	.03946	.04108	.04446	.04653	.04976	.05236	.05534	.05858	9
10	.03954	.04117	.04455	.04663	.04985	.05246	.05543	.05869	10
11	.03963	.04126	.04464	.04672	.04994	.05256	.05553	.05879	11
12	.03971	.04135	.04472	.04682	.05003	.05266	.05562	.05890	12
13	.03979	.04144	.04481	.04691	.05012	.05276	.05572	.05901	13
14	.03987	.04153	.04489	.04700	.05021	.05286	.05582	.05911	14
15	.03995	.04161	.04498	.04710	.05030	.05297	.05591	.05922	15
16	.04003	.04170	.04507	.04719	.05039	.05307	.05601	.05933	16
17	.04011	.04179	.04515	.04729	.05048	.05317	.05610	.05944	17
18	.04019	.04188	.04524	.04738	.05057	.05327	.05620	.05955	18
19	.04028	.04197	.04533	.04748	.05067	.05337	.05630	.05965	19
20	.04036	.04206	.04541	.04757	.05076	.05347	.05639	.05976	20
21	.04044	.04214	.04550	.04767	.05085	.05357	.05649	.05987	21
22	.04052	.04223	.04559	.04776	.05094	.05367	.05658	.05998	22
23	.04060	.04232	.04567	.04786	.05103	.05378	.05668	.06009	23
24	.04069	.04241	.04576	.04795	.05112	.05388	.05678	.06020	24
25	.04077	.04250	.04585	.04805	.05122	.05398	.05687	.06030	25
26	.04085	.04259	.04593	.04815	.05131	.05408	.05697	.06041	26
27	.04093	.04268	.04602	.04824	.05140	.05418	.05707	.06052	27
28	.04102	.04277	.04611	.04834	.05149	.05429	.05716	.06063	28
29	.04110	.04286	.04620	.04843	.05158	.05439	.05726	.06074	29
30	.04118	.04295	.04628	.04853	.05168	.05449	.05736	.06085	30
31	.04126	.04304	.04637	.04863	.05177	.05460	.05746	.06096	31
32	.04135	.04313	.04646	.04872	.05186	.05470	.05755	.06107	32
33	.04143	.04322	.04655	.04882	.05195	.05480	.05765	.06118	33
34	.04151	.04331	.04663	.04891	.05205	.05490	.05775	.06129	34
35	.04159	.04340	.04672	.04901	.05214	.05501	.05785	.06140	35
36	.04168	.04349	.04681	.04911	.05223	.05511	.05794	.06151	36
37	.04176	.04358	.04690	.04920	.05232	.05521	.05804	.06162	37
38	.04184	.04367	.04699	.04930	.05242	.05532	.05814	.06173	38
39	.04193	.04376	.04707	.04940	.05251	.05542	.05824	.06184	39
40	.04201	.04385	.04716	.04950	.05260	.05552	.05833	.06195	40
41	.04209	.04394	.04725	.04959	.05270	.05563	.05843	.06206	41
42	.04218	.04403	.04734	.04969	.05279	.05573	.05853	.06217	42
43	.04226	.04413	.04743	.04979	.05288	.05584	.05863	.06228	43
44	.04234	.04422	.04752	.04989	.05298	.05594	.05873	.06239	44
45	.04243	.04431	.04760	.04998	.05307	.05604	.05882	.06250	45
46	.04251	.04440	.04769	.05008	.05316	.05615	.05892	.06261	46
47	.04260	.04449	.04778	.05018	.05326	.05625	.05902	.06272	47
48	.04268	.04458	.04787	.05028	.05335	.05636	.05912	.06283	48
49	.04276	.04468	.04796	.05038	.05344	.05646	.05922	.06295	49
50	.04285	.04477	.04805	.05047	.05354	.05657	.05932	.06306	50
51	.04293	.04486	.04814	.05057	.05363	.05667	.05943	.06317	51
52	.04302	.04495	.04823	.05067	.05373	.05678	.05951	.06328	52
53	.04310	.04504	.04832	.05077	.05383	.05688	.05961	.06339	53
54	.04319	.04514	.04841	.05087	.05391	.05699	.05971	.06350	54
55	.04327	.04523	.04850	.05097	.05401	.05709	.05981	.06362	55
56	.04336	.04532	.04858	.05107	.05410	.05720	.05991	.06373	56
57	.04344	.04541	.04867	.05116	.05420	.05730	.06001	.06384	57
58	.04353	.04551	.04876	.05126	.05429	.05741	.06011	.06395	58
59	.04361	.04560	.04885	.05136	.05439	.05751	.06021	.06407	59
60	.04370	.04569	.04894	.05146	.05448	.05762	.06031	.06418	60

TABLE XIII.—VERSINES AND EXSECANTS.

	20°		21°		22°		23°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.06031	.06418	.06642	.07115	.07282	.07853	.07950	.08636	0
1	.06041	.06429	.06652	.07126	.07293	.07866	.07961	.08649	1
2	.06051	.06440	.06663	.07138	.07303	.07879	.07972	.08663	2
3	.06061	.06452	.06673	.07150	.07314	.07892	.07984	.08676	3
4	.06071	.06463	.06684	.07162	.07325	.07904	.07995	.08690	4
5	.06081	.06474	.06694	.07174	.07336	.07917	.08006	.08703	5
6	.06091	.06486	.06705	.07186	.07347	.07930	.08018	.08717	6
7	.06101	.06497	.06715	.07199	.07358	.07943	.08029	.08730	7
8	.06111	.06508	.06726	.07211	.07369	.07955	.08041	.08744	8
9	.06121	.06520	.06736	.07223	.07380	.07968	.08052	.08757	9
10	.06131	.06531	.06747	.07235	.07391	.07981	.08064	.08771	10
11	.06141	.06542	.06757	.07247	.07402	.07994	.08075	.08784	11
12	.06151	.06554	.06768	.07259	.07413	.08006	.08086	.08798	12
13	.06161	.06565	.06778	.07271	.07424	.08019	.08098	.08811	13
14	.06171	.06577	.06789	.07283	.07435	.08032	.08109	.08825	14
15	.06181	.06588	.06799	.07295	.07446	.08045	.08121	.08839	15
16	.06191	.06600	.06810	.07307	.07457	.08058	.08132	.08852	16
17	.06201	.06611	.06820	.07320	.07468	.08071	.08144	.08866	17
18	.06211	.06622	.06831	.07332	.07479	.08084	.08155	.08880	18
19	.06221	.06634	.06841	.07344	.07490	.08097	.08167	.08893	19
20	.06231	.06645	.06852	.07356	.07501	.08109	.08178	.08907	20
21	.06241	.06657	.06863	.07368	.07512	.08122	.08190	.08921	21
22	.06252	.06668	.06873	.07380	.07523	.08135	.08201	.08934	22
23	.06262	.06680	.06884	.07393	.07534	.08148	.08213	.08948	23
24	.06272	.06691	.06894	.07405	.07545	.08161	.08225	.08962	24
25	.06282	.06703	.06905	.07417	.07556	.08174	.08236	.08975	25
26	.06292	.06715	.06916	.07429	.07568	.08187	.08248	.08989	26
27	.06302	.06726	.06926	.07442	.07579	.08200	.08259	.09003	27
28	.06312	.06738	.06937	.07454	.07590	.08213	.08271	.09017	28
29	.06323	.06749	.06948	.07466	.07601	.08226	.08282	.09030	29
30	.06333	.06761	.06958	.07479	.07612	.08239	.08294	.09044	30
31	.06343	.06773	.06969	.07491	.07623	.08252	.08306	.09058	31
32	.06353	.06784	.06980	.07503	.07634	.08265	.08317	.09072	32
33	.06363	.06796	.06990	.07516	.07645	.08278	.08329	.09086	33
34	.06374	.06807	.07001	.07528	.07657	.08291	.08340	.09099	34
35	.06384	.06819	.07012	.07540	.07668	.08305	.08352	.09113	35
36	.06394	.06831	.07022	.07553	.07679	.08318	.08364	.09127	36
37	.06404	.06843	.07033	.07565	.07690	.08331	.08375	.09141	37
38	.06415	.06854	.07044	.07578	.07701	.08344	.08387	.09155	38
39	.06425	.06866	.07055	.07590	.07713	.08357	.08399	.09169	39
40	.06435	.06878	.07065	.07602	.07724	.08370	.08410	.09183	40
41	.06445	.06889	.07076	.07615	.07735	.08383	.08422	.09197	41
42	.06456	.06901	.07087	.07627	.07746	.08397	.08434	.09211	42
43	.06466	.06913	.07098	.07640	.07757	.08410	.08445	.09224	43
44	.06476	.06925	.07108	.07652	.07769	.08423	.08457	.09238	44
45	.06486	.06936	.07119	.07665	.07780	.08436	.08469	.09252	45
46	.06497	.06948	.07130	.07677	.07791	.08449	.08481	.09266	46
47	.06507	.06960	.07141	.07690	.07802	.08463	.08493	.09280	47
48	.06517	.06972	.07151	.07702	.07814	.08476	.08504	.09294	48
49	.06528	.06984	.07162	.07715	.07825	.08489	.08516	.09308	49
50	.06538	.06995	.07173	.07727	.07836	.08503	.08528	.09322	50
51	.06548	.07007	.07184	.07740	.07848	.08516	.08539	.09337	51
52	.06559	.07019	.07195	.07752	.07859	.08529	.08551	.09351	52
53	.06569	.07031	.07206	.07765	.07870	.08542	.08563	.09365	53
54	.06580	.07043	.07216	.07778	.07881	.08556	.08575	.09379	54
55	.06590	.07055	.07227	.07790	.07893	.08569	.08586	.09393	55
56	.06600	.07067	.07238	.07803	.07904	.08582	.08598	.09407	56
57	.06611	.07079	.07249	.07816	.07915	.08596	.08610	.09421	57
58	.06621	.07091	.07260	.07828	.07927	.08609	.08622	.09435	58
59	.06632	.07103	.07271	.07841	.07938	.08623	.08634	.09449	59
60	.06642	.07115	.07282	.07853	.07950	.08636	.08645	.09464	60

TABLE XIII.—VERSINES AND EXSECANTS.

°	24°		25°		26°		27°		°
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.08645	.09464	.08669	.10338	.10121	.11260	.10899	.12233	0
1	.08657	.09478	.08682	.10353	.10133	.11276	.10913	.12249	1
2	.08669	.09492	.08694	.10368	.10146	.11292	.10926	.12266	2
3	.08681	.09506	.08706	.10383	.10159	.11308	.10939	.12283	3
4	.08693	.09520	.08718	.10398	.10172	.11323	.10952	.12299	4
5	.08705	.09535	.08731	.10413	.10184	.11339	.10965	.12316	5
6	.08717	.09549	.08743	.10428	.10197	.11355	.10979	.12333	6
7	.08728	.09563	.08755	.10443	.10210	.11371	.10992	.12349	7
8	.08740	.09577	.08768	.10458	.10223	.11387	.11006	.12366	8
9	.08752	.09592	.08780	.10473	.10236	.11403	.11019	.12383	9
10	.08764	.09606	.08793	.10488	.10248	.11419	.11033	.12400	10
11	.08776	.09620	.08805	.10503	.10261	.11435	.11045	.12416	11
12	.08788	.09635	.08817	.10518	.10274	.11451	.11058	.12433	12
13	.08800	.09649	.08830	.10533	.10287	.11467	.11072	.12450	13
14	.08812	.09663	.08842	.10548	.10300	.11483	.11085	.12467	14
15	.08824	.09678	.08854	.10564	.10313	.11499	.11098	.12484	15
16	.08836	.09692	.08867	.10579	.10326	.11515	.11112	.12501	16
17	.08848	.09707	.08879	.10594	.10338	.11531	.11125	.12518	17
18	.08860	.09721	.08902	.10609	.10351	.11547	.11138	.12534	18
19	.08872	.09735	.08904	.10625	.10364	.11563	.11152	.12551	19
20	.08884	.09750	.08917	.10640	.10377	.11579	.11165	.12568	20
21	.08896	.09764	.08929	.10655	.10390	.11595	.11178	.12585	21
22	.08908	.09779	.08942	.10670	.10403	.11611	.11192	.12602	22
23	.08920	.09793	.08954	.10686	.10416	.11627	.11205	.12619	23
24	.08932	.09808	.08966	.10701	.10429	.11643	.11218	.12636	24
25	.08944	.09822	.08979	.10716	.10442	.11659	.11232	.12653	25
26	.08956	.09837	.08991	.10731	.10455	.11675	.11245	.12670	26
27	.08968	.09851	.09004	.10747	.10468	.11691	.11259	.12687	27
28	.08980	.09866	.09016	.10762	.10481	.11708	.11272	.12704	28
29	.08992	.09880	.09029	.10777	.10494	.11724	.11285	.12721	29
30	.09004	.09895	.09041	.10793	.10507	.11740	.11299	.12738	30
31	.09016	.09909	.09054	.10808	.10520	.11756	.11312	.12755	31
32	.09028	.09924	.09067	.10824	.10533	.11772	.11326	.12772	32
33	.09040	.09939	.09079	.10839	.10546	.11789	.11339	.12789	33
34	.09052	.09953	.09092	.10854	.10559	.11805	.11353	.12807	34
35	.09064	.09968	.09104	.10870	.10572	.11821	.11366	.12824	35
36	.09076	.09982	.09117	.10885	.10585	.11838	.11380	.12841	36
37	.09089	.09997	.09129	.10901	.10598	.11854	.11393	.12858	37
38	.09101	.10012	.09142	.10916	.10611	.11870	.11407	.12875	38
39	.09113	.10026	.09154	.10932	.10624	.11886	.11420	.12892	39
40	.09125	.10041	.09167	.10947	.10637	.11903	.11434	.12910	40
41	.09137	.10055	.09180	.10963	.10650	.11919	.11447	.12927	41
42	.09149	.10071	.09192	.10978	.10663	.11936	.11461	.12944	42
43	.09161	.10085	.09205	.10994	.10676	.11952	.11474	.12961	43
44	.09174	.10100	.09218	.11009	.10689	.11968	.11488	.12979	44
45	.09186	.10115	.09230	.11025	.10702	.11985	.11501	.12996	45
46	.09198	.10130	.09243	.11041	.10715	.12001	.11515	.13013	46
47	.09210	.10144	.09255	.11056	.10728	.12018	.11528	.13031	47
48	.09222	.10159	.09268	.11072	.10741	.12034	.11542	.13048	48
49	.09234	.10174	.09281	.11087	.10755	.12051	.11555	.13065	49
50	.09247	.10189	.09293	.11103	.10768	.12067	.11569	.13083	50
51	.09259	.10204	.10006	.11119	.10781	.12084	.11583	.13100	51
52	.09271	.10218	.10019	.11134	.10794	.12100	.11596	.13117	52
53	.09283	.10233	.10032	.11150	.10807	.12117	.11610	.13135	53
54	.09296	.10248	.10044	.11166	.10820	.12133	.11623	.13152	54
55	.09308	.10263	.10057	.11181	.10833	.12150	.11637	.13170	55
56	.09320	.10278	.10070	.11197	.10847	.12166	.11651	.13187	56
57	.09332	.10293	.10082	.11213	.10860	.12183	.11664	.13205	57
58	.09345	.10308	.10095	.11229	.10873	.12199	.11678	.13222	58
59	.09357	.10323	.10108	.11244	.10886	.12216	.11692	.13240	59
60	.09369	.10338	.10121	.11260	.10899	.12233	.11705	.13257	60

TABLE XIII.—VERSINES AND EXSECANTS.

	28°		29°		30°		31°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.11705	.13257	.12538	.14335	.13397	.15470	.14283	.16663	0
1	.11719	.13275	.12553	.14354	.13412	.15489	.14298	.16684	1
2	.11733	.13292	.12566	.14373	.13427	.15509	.14313	.16704	2
3	.11746	.13310	.12580	.14391	.13441	.15528	.14328	.16725	3
4	.11760	.13327	.12595	.14409	.13456	.15548	.14343	.16745	4
5	.11774	.13345	.12609	.14428	.13470	.15567	.14358	.16766	5
6	.11787	.13362	.12623	.14446	.13485	.15587	.14373	.16786	6
7	.11801	.13380	.12637	.14465	.13499	.15606	.14388	.16806	7
8	.11815	.13398	.12651	.14483	.13514	.15626	.14403	.16827	8
9	.11828	.13415	.12665	.14502	.13529	.15645	.14418	.16848	9
10	.11842	.13433	.12679	.14521	.13543	.15665	.14433	.16868	10
11	.11856	.13451	.12694	.14539	.13558	.15684	.14449	.16889	11
12	.11870	.13468	.12708	.14558	.13573	.15704	.14464	.16909	12
13	.11883	.13486	.12722	.14576	.13587	.15724	.14479	.16930	13
14	.11897	.13504	.12736	.14595	.13602	.15743	.14494	.16950	14
15	.11911	.13521	.12750	.14614	.13616	.15763	.14509	.16971	15
16	.11925	.13539	.12765	.14632	.13631	.15782	.14524	.16992	16
17	.11938	.13557	.12779	.14651	.13646	.15802	.14539	.17012	17
18	.11952	.13575	.12793	.14670	.13660	.15822	.14554	.17033	18
19	.11966	.13593	.12807	.14689	.13675	.15841	.14569	.17054	19
20	.11980	.13610	.12822	.14707	.13690	.15861	.14584	.17075	20
21	.11994	.13628	.12836	.14726	.13705	.15881	.14599	.17095	21
22	.12007	.13646	.12850	.14745	.13719	.15901	.14615	.17116	22
23	.12021	.13664	.12864	.14764	.13734	.15920	.14630	.17137	23
24	.12035	.13682	.12879	.14783	.13749	.15940	.14645	.17158	24
25	.12049	.13700	.12893	.14801	.13763	.15960	.14660	.17178	25
26	.12063	.13718	.12907	.14820	.13778	.15980	.14675	.17199	26
27	.12077	.13735	.12921	.14839	.13793	.16000	.14690	.17220	27
28	.12091	.13753	.12936	.14858	.13808	.16019	.14706	.17241	28
29	.12104	.13771	.12950	.14877	.13822	.16039	.14721	.17262	29
30	.12118	.13789	.12964	.14896	.13837	.16059	.14736	.17283	30
31	.12132	.13807	.12979	.14914	.13852	.16079	.14751	.17304	31
32	.12146	.13825	.12993	.14933	.13867	.16099	.14766	.17325	32
33	.12160	.13843	.13007	.14952	.13881	.16119	.14782	.17346	33
34	.12174	.13861	.13022	.14971	.13896	.16139	.14797	.17367	34
35	.12188	.13879	.13036	.14990	.13911	.16159	.14812	.17388	35
36	.12202	.13897	.13051	.15009	.13926	.16179	.14827	.17409	36
37	.12216	.13916	.13065	.15028	.13941	.16199	.14843	.17430	37
38	.12230	.13934	.13079	.15047	.13955	.16219	.14858	.17451	38
39	.12244	.13952	.13094	.15066	.13970	.16239	.14873	.17472	39
40	.12257	.13970	.13108	.15085	.13985	.16259	.14888	.17493	40
41	.12271	.13988	.13123	.15105	.14000	.16279	.14904	.17514	41
42	.12285	.14006	.13137	.15124	.14015	.16299	.14919	.17535	42
43	.12299	.14024	.13151	.15143	.14030	.16319	.14934	.17556	43
44	.12313	.14042	.13166	.15163	.14044	.16339	.14949	.17577	44
45	.12327	.14061	.13180	.15181	.14059	.16359	.14965	.17598	45
46	.12341	.14079	.13195	.15200	.14074	.16380	.14980	.17620	46
47	.12355	.14097	.13209	.15219	.14089	.16400	.14995	.17641	47
48	.12369	.14115	.13223	.15239	.14104	.16420	.15011	.17662	48
49	.12383	.14134	.13238	.15258	.14119	.16440	.15026	.17683	49
50	.12397	.14152	.13252	.15277	.14134	.16460	.15041	.17704	50
51	.12411	.14170	.13267	.15296	.14149	.16481	.15057	.17726	51
52	.12425	.14188	.13281	.15315	.14164	.16501	.15072	.17747	52
53	.12439	.14207	.13296	.15335	.14179	.16521	.15087	.17768	53
54	.12454	.14225	.13310	.15354	.14194	.16541	.15103	.17790	54
55	.12468	.14243	.13325	.15373	.14208	.16562	.15118	.17811	55
56	.12482	.14262	.13339	.15393	.14223	.16582	.15134	.17832	56
57	.12496	.14280	.13354	.15412	.14238	.16602	.15149	.17854	57
58	.12510	.14299	.13368	.15431	.14253	.16623	.15164	.17875	58
59	.12524	.14317	.13383	.15451	.14268	.16643	.15180	.17896	59
60	.12538	.14335	.13397	.15470	.14283	.16663	.15195	.17918	60

TABLE XIII.—VERSINES AND EXSECANTS.

	32°		33°		34°		35°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.15195	.17918	.16133	.19236	.17096	.20622	.18085	.22077	0
1	.15211	.17939	.16149	.19259	.17113	.20645	.18101	.22102	1
2	.15226	.17961	.16165	.19281	.17129	.20669	.18118	.22127	2
3	.15241	.17982	.16181	.19304	.17145	.20693	.18135	.22152	3
4	.15257	.18004	.16196	.19327	.17161	.20717	.18152	.22177	4
5	.15272	.18025	.16212	.19349	.17178	.20740	.18168	.22202	5
6	.15288	.18047	.16228	.19372	.17194	.20764	.18185	.22227	6
7	.15303	.18068	.16244	.19394	.17210	.20788	.18202	.22253	7
8	.15319	.18090	.16260	.19417	.17227	.20812	.18218	.22277	8
9	.15334	.18111	.16276	.19440	.17243	.20836	.18235	.22302	9
10	.15350	.18133	.16292	.19463	.17259	.20859	.18252	.22327	10
11	.15365	.18155	.16308	.19485	.17276	.20883	.18269	.22352	11
12	.15381	.18176	.16324	.19508	.17292	.20907	.18286	.22377	12
13	.15396	.18198	.16340	.19531	.17308	.20931	.18302	.22402	13
14	.15412	.18220	.16355	.19554	.17325	.20955	.18319	.22428	14
15	.15427	.18241	.16371	.19576	.17341	.20979	.18336	.22453	15
16	.15443	.18263	.16387	.19599	.17357	.21003	.18353	.22478	16
17	.15458	.18285	.16403	.19622	.17374	.21027	.18369	.22503	17
18	.15474	.18307	.16419	.19645	.17390	.21051	.18386	.22528	18
19	.15489	.18328	.16435	.19668	.17407	.21075	.18403	.22554	19
20	.15505	.18350	.16451	.19691	.17423	.21099	.18420	.22579	20
21	.15520	.18372	.16467	.19713	.17439	.21123	.18437	.22604	21
22	.15536	.18394	.16483	.19736	.17456	.21147	.18454	.22629	22
23	.15552	.18416	.16499	.19759	.17472	.21171	.18470	.22655	23
24	.15567	.18437	.16515	.19782	.17489	.21195	.18487	.22680	24
25	.15583	.18459	.16531	.19805	.17505	.21220	.18504	.22706	25
26	.15598	.18481	.16547	.19828	.17522	.21244	.18521	.22731	26
27	.15614	.18503	.16563	.19851	.17538	.21268	.18538	.22756	27
28	.15630	.18525	.16579	.19874	.17554	.21292	.18555	.22782	28
29	.15645	.18547	.16595	.19897	.17571	.21316	.18572	.22807	29
30	.15661	.18569	.16611	.19920	.17587	.21341	.18588	.22833	30
31	.15676	.18591	.16627	.19944	.17604	.21365	.18605	.22858	31
32	.15692	.18613	.16644	.19967	.17620	.21389	.18622	.22884	32
33	.15708	.18635	.16660	.19990	.17637	.21414	.18639	.22909	33
34	.15723	.18657	.16676	.20018	.17653	.21438	.18656	.22935	34
35	.15739	.18679	.16692	.20036	.17670	.21462	.18673	.22960	35
36	.15755	.18701	.16708	.20059	.17686	.21487	.18690	.22986	36
37	.15770	.18723	.16724	.20083	.17703	.21511	.18707	.23012	37
38	.15786	.18745	.16740	.20106	.17719	.21535	.18724	.23037	38
39	.15802	.18767	.16756	.20129	.17736	.21560	.18741	.23063	39
40	.15818	.18790	.16772	.20152	.17752	.21584	.18758	.23089	40
41	.15833	.18812	.16788	.20176	.17769	.21609	.18775	.23114	41
42	.15849	.18834	.16805	.20199	.17786	.21633	.18792	.23140	42
43	.15865	.18856	.16821	.20222	.17802	.21658	.18809	.23166	43
44	.15880	.18878	.16837	.20246	.17819	.21682	.18826	.23192	44
45	.15896	.18901	.16853	.20269	.17835	.21707	.18843	.23217	45
46	.15912	.18923	.16869	.20292	.17852	.21731	.18860	.23243	46
47	.15928	.18945	.16885	.20316	.17868	.21756	.18877	.23269	47
48	.15943	.18967	.16902	.20339	.17885	.21781	.18894	.23295	48
49	.15959	.18990	.16918	.20363	.17902	.21805	.18911	.23321	49
50	.15975	.19012	.16934	.20386	.17918	.21830	.18928	.23347	50
51	.15991	.19034	.16950	.20410	.17935	.21855	.18945	.23373	51
52	.16006	.19057	.16966	.20433	.17952	.21879	.18962	.23399	52
53	.16022	.19079	.16983	.20457	.17968	.21904	.18979	.23424	53
54	.16038	.19102	.16999	.20480	.17985	.21929	.18996	.23450	54
55	.16054	.19124	.17015	.20504	.18001	.21953	.19013	.23476	55
56	.16070	.19146	.17031	.20527	.18018	.21978	.19030	.23502	56
57	.16085	.19169	.17047	.20551	.18035	.22003	.19047	.23528	57
58	.16101	.19191	.17064	.20575	.18051	.22028	.19064	.23555	58
59	.16117	.19214	.17080	.20598	.18068	.22053	.19081	.23581	59
60	.16133	.19236	.17096	.20622	.18085	.22077	.19098	.23607	60

TABLE XIII.—VERSINES AND EXSECANTS.

	36°		37°		38°		39°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.19098	.23607	.20136	.25214	.21199	.26902	.22285	.28676	0
1	.19115	.23633	.20154	.25241	.21217	.26931	.22304	.28706	1
2	.19133	.23659	.20171	.25269	.21235	.26960	.22322	.28737	2
3	.19150	.23685	.20189	.25296	.21253	.26988	.22340	.28767	3
4	.19167	.23711	.20207	.25324	.21271	.27017	.22359	.28797	4
5	.19184	.23738	.20224	.25351	.21289	.27046	.22377	.28828	5
6	.19201	.23764	.20242	.25379	.21307	.27075	.22395	.28858	6
7	.19218	.23790	.20259	.25406	.21324	.27104	.22414	.28889	7
8	.19235	.23816	.20277	.25434	.21342	.27133	.22432	.28919	8
9	.19252	.23843	.20294	.25462	.21360	.27162	.22450	.28950	9
10	.19270	.23869	.20312	.25489	.21378	.27191	.22469	.28980	10
11	.19287	.23895	.20329	.25517	.21396	.27221	.22487	.29011	11
12	.19304	.23922	.20347	.25545	.21414	.27250	.22505	.29042	12
13	.19321	.23948	.20365	.25572	.21432	.27279	.22524	.29072	13
14	.19338	.23975	.20382	.25600	.21450	.27308	.22542	.29103	14
15	.19356	.24001	.20400	.25628	.21468	.27337	.22561	.29133	15
16	.19373	.24028	.20417	.25656	.21486	.27366	.22579	.29164	16
17	.19390	.24054	.20435	.25683	.21504	.27396	.22598	.29195	17
18	.19407	.24081	.20453	.25711	.21522	.27425	.22616	.29226	18
19	.19424	.24107	.20470	.25739	.21540	.27454	.22634	.29256	19
20	.19442	.24134	.20488	.25767	.21558	.27483	.22653	.29287	20
21	.19459	.24160	.20506	.25795	.21576	.27513	.22671	.29318	21
22	.19476	.24187	.20523	.25823	.21595	.27542	.22690	.29349	22
23	.19493	.24213	.20541	.25851	.21613	.27572	.22708	.29380	23
24	.19511	.24240	.20559	.25879	.21631	.27601	.22727	.29411	24
25	.19528	.24267	.20576	.25907	.21649	.27630	.22745	.29442	25
26	.19545	.24293	.20594	.25935	.21667	.27660	.22764	.29473	26
27	.19562	.24320	.20612	.25963	.21685	.27689	.22782	.29504	27
28	.19580	.24347	.20629	.25991	.21703	.27719	.22801	.29535	28
29	.19597	.24373	.20647	.26019	.21721	.27748	.22819	.29566	29
30	.19614	.24400	.20665	.26047	.21739	.27775	.22838	.29597	30
31	.19632	.24427	.20682	.26075	.21757	.27807	.22856	.29628	31
32	.19649	.24454	.20700	.26104	.21775	.27837	.22875	.29659	32
33	.19666	.24481	.20718	.26132	.21794	.27867	.22893	.29690	33
34	.19684	.24508	.20736	.26160	.21812	.27896	.22912	.29721	34
35	.19701	.24534	.20753	.26188	.21830	.27926	.22930	.29752	35
36	.19718	.24561	.20771	.26216	.21848	.27956	.22949	.29784	36
37	.19736	.24588	.20789	.26245	.21866	.27985	.22967	.29815	37
38	.19753	.24615	.20807	.26273	.21884	.28015	.22986	.29846	38
39	.19770	.24642	.20824	.26301	.21902	.28045	.23004	.29877	39
40	.19788	.24669	.20842	.26330	.21921	.28075	.23023	.29909	40
41	.19805	.24696	.20860	.26358	.21939	.28105	.23041	.29940	41
42	.19822	.24723	.20878	.26387	.21957	.28134	.23060	.29971	42
43	.19840	.24750	.20895	.26415	.21975	.28164	.23079	.30003	43
44	.19857	.24777	.20913	.26443	.21993	.28194	.23097	.30034	44
45	.19875	.24804	.20931	.26472	.22012	.28224	.23116	.30066	45
46	.19892	.24832	.20949	.26500	.22030	.28254	.23134	.30097	46
47	.19909	.24859	.20967	.26529	.22048	.28284	.23153	.30129	47
48	.19927	.24886	.20985	.26557	.22066	.28314	.23172	.30160	48
49	.19944	.24913	.21002	.26586	.22084	.28344	.23190	.30192	49
50	.19962	.24940	.21020	.26615	.22103	.28374	.23209	.30223	50
51	.19979	.24967	.21038	.26643	.22121	.28404	.23228	.30255	51
52	.19997	.24995	.21056	.26672	.22139	.28434	.23246	.30287	52
53	.20014	.25022	.21074	.26701	.22157	.28464	.23265	.30318	53
54	.20032	.25049	.21092	.26729	.22176	.28495	.23283	.30350	54
55	.20049	.25077	.21109	.26758	.22194	.28525	.23302	.30382	55
56	.20066	.25104	.21127	.26787	.22212	.28555	.23321	.30413	56
57	.20084	.25131	.21145	.26815	.22231	.28585	.23339	.30445	57
58	.20101	.25159	.21163	.26844	.22249	.28615	.23358	.30477	58
59	.20119	.25186	.21181	.26873	.22267	.28646	.23377	.30509	59
60	.20136	.25214	.21199	.26902	.22285	.28676	.23396	.30541	60

TABLE XIII.—VERSINES AND EXSECANTS.

	40°		41°		42°		43°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.23396	.30541	.24529	.32501	.25686	.34563	.26865	.36738	0
1	.23414	.30673	.24548	.32535	.25705	.34599	.26884	.36770	1
2	.23433	.30605	.24567	.32568	.25724	.34634	.26904	.36807	2
3	.23452	.30636	.24586	.32602	.25744	.34669	.26924	.36844	3
4	.23470	.30668	.24605	.32636	.25763	.34704	.26944	.36881	4
5	.23489	.30700	.24625	.32669	.25783	.34740	.26964	.36919	5
6	.23508	.30732	.24644	.32703	.25802	.34775	.26984	.36956	6
7	.23527	.30764	.24663	.32737	.25822	.34811	.27004	.36993	7
8	.23545	.30796	.24682	.32770	.25841	.34846	.27024	.37030	8
9	.23564	.30829	.24701	.32804	.25861	.34883	.27043	.37068	9
10	.23583	.30861	.24720	.32838	.25880	.34917	.27063	.37105	10
11	.23602	.30893	.24739	.32872	.25900	.34953	.27083	.37143	11
12	.23620	.30925	.24759	.32905	.25920	.34988	.27103	.37180	12
13	.23639	.30957	.24778	.32939	.25939	.35024	.27123	.37218	13
14	.23658	.30989	.24797	.32973	.25959	.35060	.27143	.37255	14
15	.23677	.31022	.24816	.33007	.25978	.35096	.27163	.37293	15
16	.23696	.31054	.24835	.33041	.25998	.35131	.27183	.37330	16
17	.23714	.31086	.24854	.33075	.26017	.35167	.27203	.37368	17
18	.23733	.31119	.24874	.33109	.26037	.35203	.27223	.37406	18
19	.23752	.31151	.24893	.33143	.26056	.35238	.27243	.37443	19
20	.23771	.31183	.24912	.33177	.26076	.35274	.27263	.37481	20
21	.23790	.31216	.24931	.33211	.26096	.35310	.27283	.37519	21
22	.23808	.31248	.24950	.33245	.26115	.35346	.27303	.37556	22
23	.23827	.31281	.24970	.33279	.26135	.35382	.27323	.37594	23
24	.23846	.31313	.24989	.33314	.26154	.35418	.27343	.37632	24
25	.23865	.31346	.25008	.33348	.26174	.35454	.27363	.37670	25
26	.23884	.31378	.25027	.33382	.26194	.35490	.27383	.37708	26
27	.23903	.31411	.25047	.33416	.26213	.35526	.27403	.37746	27
28	.23922	.31443	.25066	.33451	.26233	.35562	.27423	.37784	28
29	.23941	.31476	.25085	.33485	.26253	.35598	.27443	.37822	29
30	.23959	.31509	.25104	.33519	.26272	.35634	.27463	.37860	30
31	.23978	.31541	.25124	.33554	.26292	.35670	.27483	.37898	31
32	.23997	.31574	.25143	.33588	.26312	.35707	.27503	.37936	32
33	.24016	.31607	.25162	.33622	.26331	.35743	.27523	.37974	33
34	.24035	.31640	.25182	.33657	.26351	.35779	.27543	.38012	34
35	.24054	.31672	.25201	.33691	.26371	.35815	.27563	.38051	35
36	.24073	.31705	.25220	.33726	.26390	.35852	.27583	.38089	36
37	.24092	.31738	.25240	.33760	.26410	.35888	.27603	.38127	37
38	.24111	.31771	.25259	.33795	.26430	.35924	.27623	.38165	38
39	.24130	.31804	.25278	.33830	.26449	.35961	.27643	.38204	39
40	.24149	.31837	.25297	.33864	.26469	.35997	.27663	.38242	40
41	.24168	.31870	.25317	.33899	.26489	.36034	.27683	.38280	41
42	.24187	.31903	.25336	.33934	.26509	.36070	.27703	.38319	42
43	.24206	.31936	.25356	.33968	.26528	.36107	.27723	.38357	43
44	.24225	.31969	.25375	.34003	.26548	.36143	.27743	.38396	44
45	.24244	.32002	.25394	.34038	.26568	.36180	.27764	.38434	45
46	.24263	.32035	.25414	.34073	.26588	.36217	.27784	.38473	46
47	.24281	.32068	.25433	.34108	.26607	.36253	.27804	.38512	47
48	.24300	.32101	.25452	.34142	.26627	.36290	.27824	.38550	48
49	.24320	.32134	.25472	.34177	.26647	.36327	.27844	.38589	49
50	.24339	.32168	.25491	.34212	.26667	.36363	.27864	.38628	50
51	.24358	.32201	.25511	.34247	.26686	.36400	.27884	.38666	51
52	.24377	.32234	.25530	.34282	.26706	.36437	.27905	.38705	52
53	.24396	.32267	.25549	.34317	.26726	.36474	.27925	.38744	53
54	.24415	.32301	.25569	.34352	.26746	.36511	.27945	.38783	54
55	.24434	.32334	.25588	.34387	.26766	.36548	.27965	.38822	55
56	.24453	.32368	.25608	.34423	.26785	.36585	.27985	.38860	56
57	.24472	.32401	.25627	.34458	.26805	.36622	.28005	.38899	57
58	.24491	.32434	.25647	.34493	.26825	.36659	.28026	.38938	58
59	.24510	.32468	.25666	.34528	.26845	.36696	.28046	.38977	59
60	.24529	.32501	.25686	.34563	.26865	.36733	.28066	.39016	60

TABLE XIII.—VERSINES AND EXSECANTS.

	44°		45°		46°		47°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.28066	.39016	.29289	.41421	.30534	.43956	.31800	.46028	0
1	.28066	.39055	.29310	.41463	.30555	.43999	.31821	.46074	1
2	.28106	.39095	.29330	.41504	.30576	.44049	.31843	.46119	2
3	.28127	.39134	.29351	.41545	.30597	.44096	.31864	.46165	3
4	.28147	.39173	.29372	.41586	.30618	.44129	.31885	.46211	4
5	.28167	.39212	.29392	.41627	.30639	.44173	.31907	.46257	5
6	.28187	.39251	.29413	.41669	.30660	.44217	.31928	.46303	6
7	.28208	.39291	.29433	.41710	.30681	.44260	.31949	.46349	7
8	.28228	.39330	.29454	.41752	.30702	.44304	.31971	.46395	8
9	.28248	.39369	.29475	.41793	.30723	.44347	.31992	.47041	9
10	.28268	.39409	.29495	.41835	.30744	.44391	.32013	.47087	10
11	.28289	.39448	.29516	.41876	.30765	.44435	.32035	.47134	11
12	.28309	.39487	.29537	.41918	.30786	.44479	.32056	.47180	12
13	.28329	.39527	.29557	.41959	.30807	.44523	.32077	.47226	13
14	.28350	.39566	.29578	.42001	.30828	.44567	.32099	.47272	14
15	.28370	.39606	.29599	.42042	.30849	.44610	.32120	.47319	15
16	.28390	.39646	.29619	.42084	.30870	.44654	.32141	.47365	16
17	.28410	.39685	.29640	.42126	.30891	.44698	.32163	.47411	17
18	.28431	.39725	.29661	.42168	.30912	.44742	.32184	.47458	18
19	.28451	.39764	.29681	.42210	.30933	.44787	.32205	.47504	19
20	.28471	.39804	.29703	.42251	.30954	.44831	.32227	.47551	20
21	.28492	.39844	.29723	.42293	.30975	.44875	.32248	.47598	21
22	.28512	.39884	.29743	.42335	.30996	.44919	.32270	.47644	22
23	.28532	.39924	.29764	.42377	.31017	.44963	.32291	.47691	23
24	.28553	.39968	.29785	.42419	.31038	.45007	.32312	.47738	24
25	.28573	.40008	.29805	.42461	.31059	.45052	.32334	.47784	25
26	.28593	.40048	.29826	.42503	.31080	.45096	.32355	.47831	26
27	.28614	.40088	.29847	.42545	.31101	.45141	.32377	.47878	27
28	.28634	.40128	.29868	.42587	.31122	.45185	.32398	.47925	28
29	.28655	.40168	.29888	.42630	.31143	.45229	.32420	.47972	29
30	.28675	.40208	.29909	.42672	.31165	.45274	.32441	.48019	30
31	.28695	.40248	.29930	.42714	.31186	.45319	.32462	.48066	31
32	.28716	.40288	.29951	.42756	.31207	.45363	.32484	.48113	32
33	.28736	.40324	.29971	.42799	.31228	.45408	.32505	.48160	33
34	.28757	.40364	.29992	.42841	.31249	.45452	.32527	.48207	34
35	.28777	.40404	.30013	.42883	.31270	.45497	.32548	.48254	35
36	.28797	.40444	.30034	.42926	.31291	.45542	.32570	.48301	36
37	.28818	.40485	.30054	.42968	.31312	.45587	.32591	.48349	37
38	.28838	.40525	.30075	.43011	.31334	.45631	.32613	.48396	38
39	.28859	.40565	.30096	.43053	.31355	.45676	.32634	.48443	39
40	.28879	.40606	.30117	.43096	.31376	.45721	.32656	.48491	40
41	.28900	.40646	.30138	.43139	.31397	.45766	.32677	.48538	41
42	.28920	.40687	.30158	.43181	.31418	.45811	.32699	.48586	42
43	.28941	.40727	.30179	.43224	.31439	.45856	.32720	.48633	43
44	.28961	.40768	.30200	.43267	.31461	.45901	.32742	.48681	44
45	.28981	.40808	.30221	.43310	.31482	.45946	.32763	.48728	45
46	.29002	.40849	.30242	.43352	.31503	.45992	.32785	.48776	46
47	.29022	.40890	.30263	.43395	.31524	.46037	.32806	.48824	47
48	.29043	.40930	.30283	.43438	.31545	.46082	.32828	.48871	48
49	.29063	.40971	.30304	.43481	.31567	.46127	.32849	.48919	49
50	.29084	.41012	.30325	.43524	.31588	.46173	.32871	.48967	50
51	.29104	.41053	.30346	.43567	.31609	.46218	.32893	.49015	51
52	.29125	.41093	.30367	.43610	.31630	.46263	.32914	.49063	52
53	.29145	.41134	.30388	.43653	.31651	.46309	.32936	.49111	53
54	.29166	.41175	.30409	.43696	.31673	.46354	.32957	.49159	54
55	.29187	.41216	.30430	.43739	.31694	.46400	.32979	.49207	55
56	.29207	.41257	.30451	.43783	.31715	.46445	.33001	.49255	56
57	.29228	.41298	.30471	.43826	.31736	.46491	.33022	.49303	57
58	.29248	.41339	.30492	.43869	.31758	.46537	.33044	.49351	58
59	.29269	.41380	.30513	.43912	.31779	.46582	.33065	.49399	59
60	.29289	.41421	.30534	.43956	.31800	.46628	.33087	.49448	60

TABLE XIII.—VERSINES AND EXSECANTS.

	48°		49°		50°		51°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.83087	.49448	.84394	.52425	.85721	.55572	.87068	.58902	0
1	.83109	.49496	.84416	.52476	.85744	.55626	.87091	.58959	1
2	.83130	.49544	.84438	.52527	.85766	.55680	.87113	.59016	2
3	.83152	.49593	.84460	.52579	.85788	.55734	.87136	.59073	3
4	.83173	.49641	.84482	.52630	.85810	.55789	.87158	.59130	4
5	.83195	.49690	.84504	.52681	.85833	.55843	.87181	.59188	5
6	.83217	.49738	.84526	.52732	.85855	.55897	.87204	.59245	6
7	.83238	.49787	.84548	.52784	.85877	.55951	.87226	.59302	7
8	.83260	.49835	.84570	.52835	.85900	.56005	.87249	.59360	8
9	.83282	.49884	.84592	.52886	.85922	.56060	.87272	.59418	9
10	.83303	.49933	.84614	.52938	.85944	.56114	.87294	.59475	10
11	.83325	.49981	.84636	.52989	.85967	.56169	.87317	.59533	11
12	.83347	.50030	.84658	.53041	.85989	.56223	.87340	.59590	12
13	.83368	.50079	.84680	.53092	.86011	.56278	.87362	.59648	13
14	.83390	.50128	.84702	.53144	.86034	.56332	.87385	.59706	14
15	.83412	.50177	.84724	.53196	.86056	.56387	.87408	.59764	15
16	.83434	.50226	.84746	.53247	.86078	.56442	.87430	.59822	16
17	.83455	.50275	.84768	.53299	.86101	.56497	.87453	.59880	17
18	.83477	.50324	.84790	.53351	.86123	.56551	.87476	.59938	18
19	.83499	.50373	.84812	.53403	.86146	.56606	.87498	.59996	19
20	.83520	.50422	.84834	.53455	.86168	.56661	.87521	.60054	20
21	.83542	.50471	.84856	.53507	.86190	.56716	.87544	.60112	21
22	.83564	.50521	.84878	.53559	.86213	.56771	.87567	.60171	22
23	.83586	.50570	.84900	.53611	.86235	.56826	.87589	.60229	23
24	.83607	.50619	.84923	.53663	.86258	.56881	.87612	.60287	24
25	.83629	.50669	.84945	.53715	.86280	.56937	.87635	.60346	25
26	.83651	.50718	.84967	.53768	.86302	.56992	.87658	.60404	26
27	.83673	.50767	.84989	.53820	.86325	.57047	.87680	.60463	27
28	.83694	.50817	.85011	.53872	.86347	.57102	.87703	.60521	28
29	.83716	.50866	.85033	.53924	.86370	.57158	.87726	.60580	29
30	.83738	.50916	.85055	.53977	.86392	.57213	.87749	.60639	30
31	.83760	.50966	.85077	.54029	.86415	.57269	.87771	.60698	31
32	.83782	.51015	.85099	.54082	.86437	.57324	.87794	.60756	32
33	.83803	.51065	.85122	.54134	.86460	.57380	.87817	.60815	33
34	.83825	.51115	.85144	.54187	.86482	.57436	.87840	.60874	34
35	.83847	.51165	.85166	.54240	.86504	.57491	.87862	.60933	35
36	.83869	.51215	.85188	.54292	.86527	.57547	.87885	.60992	36
37	.83891	.51265	.85210	.54345	.86549	.57603	.87908	.61051	37
38	.83912	.51314	.85232	.54398	.86572	.57659	.87931	.61111	38
39	.83934	.51364	.85254	.54451	.86594	.57715	.87954	.61170	39
40	.83956	.51415	.85277	.54504	.86617	.57771	.87976	.61229	40
41	.83978	.51465	.85299	.54557	.86639	.57827	.87999	.61288	41
42	.84000	.51515	.85321	.54610	.86662	.57883	.88022	.61348	42
43	.84022	.51565	.85343	.54663	.86684	.57939	.88045	.61407	43
44	.84044	.51615	.85365	.54716	.86707	.57995	.88068	.61467	44
45	.84065	.51665	.85388	.54769	.86729	.58051	.88091	.61526	45
46	.84087	.51716	.85410	.54822	.86752	.58108	.88113	.61586	46
47	.84109	.51766	.85432	.54876	.86775	.58164	.88136	.61646	47
48	.84131	.51817	.85454	.54929	.86797	.58221	.88159	.61705	48
49	.84153	.51867	.85476	.54982	.86820	.58277	.88182	.61765	49
50	.84175	.51918	.85499	.55036	.86842	.58333	.88205	.61825	50
51	.84197	.51968	.85521	.55089	.86865	.58390	.88228	.61885	51
52	.84219	.52019	.85543	.55143	.86887	.58447	.88251	.61945	52
53	.84241	.52069	.85565	.55196	.86910	.58503	.88274	.62005	53
54	.84262	.52120	.85588	.55250	.86932	.58560	.88296	.62065	54
55	.84284	.52171	.85610	.55303	.86955	.58617	.88319	.62125	55
56	.84306	.52222	.85632	.55357	.86978	.58674	.88342	.62185	56
57	.84328	.52273	.85654	.55411	.87000	.58731	.88365	.62246	57
58	.84350	.52323	.85677	.55465	.87023	.58788	.88388	.62306	58
59	.84372	.52374	.85699	.55518	.87045	.58845	.88411	.62366	59
60	.84394	.52425	.85721	.55572	.87068	.58902	.88434	.62427	60

TABLE XIII.—VERSINES AND EXSECANTS.

	52°		53°		54°		55°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.88434	.62427	.89819	.66164	.41221	.70130	.42642	.74345	0
1	.88457	.62487	.89842	.66228	.41245	.70198	.42666	.74417	1
2	.88480	.62548	.89865	.66292	.41269	.70267	.42690	.74490	2
3	.88503	.62609	.89888	.66357	.41292	.70335	.42714	.74562	3
4	.88526	.62669	.89911	.66421	.41316	.70403	.42738	.74635	4
5	.88549	.62730	.89935	.66486	.41339	.70472	.42762	.74708	5
6	.88571	.62791	.89958	.66550	.41363	.70540	.42785	.74781	6
7	.88594	.62852	.89981	.66615	.41386	.70609	.42809	.74854	7
8	.88617	.62913	.40005	.66679	.41410	.70677	.42833	.74927	8
9	.88640	.62974	.40028	.66744	.41433	.70746	.42857	.75000	9
10	.88663	.63035	.40051	.66809	.41457	.70815	.42881	.75073	10
11	.88686	.63096	.40074	.66873	.41481	.70884	.42905	.75146	11
12	.88709	.63157	.40098	.66938	.41504	.70953	.42929	.75219	12
13	.88732	.63218	.40121	.67003	.41528	.71022	.42953	.75293	13
14	.88755	.63279	.40144	.67068	.41551	.71091	.42976	.75366	14
15	.88778	.63341	.40168	.67133	.41575	.71160	.43000	.75440	15
16	.88801	.63402	.40191	.67199	.41599	.71229	.43024	.75513	16
17	.88824	.63464	.40214	.67264	.41622	.71298	.43048	.75587	17
18	.88847	.63525	.40237	.67329	.41646	.71368	.43072	.75661	18
19	.88870	.63587	.40261	.67394	.41670	.71437	.43096	.75734	19
20	.88893	.63648	.40284	.67460	.41693	.71506	.43120	.75808	20
21	.88916	.63710	.40307	.67525	.41717	.71576	.43144	.75882	21
22	.88939	.63772	.40331	.67591	.41740	.71646	.43168	.75956	22
23	.88962	.63834	.40354	.67656	.41764	.71715	.43192	.76031	23
24	.88985	.63895	.40378	.67722	.41788	.71785	.43216	.76105	24
25	.89009	.63957	.40401	.67788	.41811	.71855	.43240	.76179	25
26	.89032	.64019	.40424	.67853	.41835	.71925	.43264	.76253	26
27	.89055	.64081	.40448	.67919	.41859	.71995	.43287	.76328	27
28	.89078	.64144	.40471	.67985	.41882	.72065	.43311	.76402	28
29	.89101	.64206	.40494	.68051	.41906	.72135	.43335	.76477	29
30	.89124	.64268	.40518	.68117	.41930	.72205	.43359	.76552	30
31	.89147	.64330	.40541	.68183	.41953	.72275	.43383	.76626	31
32	.89170	.64393	.40565	.68250	.41977	.72346	.43407	.76701	32
33	.89193	.64455	.40588	.68316	.42001	.72416	.43431	.76776	33
34	.89216	.64518	.40611	.68382	.42024	.72487	.43455	.76851	34
35	.89239	.64580	.40635	.68449	.42048	.72557	.43479	.76926	35
36	.89262	.64643	.40658	.68515	.42072	.72628	.43503	.77001	36
37	.89286	.64705	.40682	.68582	.42096	.72698	.43527	.77077	37
38	.89309	.64768	.40705	.68648	.42119	.72769	.43551	.77152	38
39	.89332	.64831	.40728	.68715	.42143	.72840	.43575	.77227	39
40	.89355	.64894	.40752	.68782	.42167	.72911	.43599	.77303	40
41	.89378	.64957	.40775	.68848	.42191	.72982	.43623	.77378	41
42	.89401	.65020	.40799	.68915	.42214	.73053	.43647	.77454	42
43	.89424	.65083	.40822	.68982	.42238	.73124	.43671	.77530	43
44	.89447	.65146	.40846	.69049	.42262	.73195	.43695	.77606	44
45	.89471	.65209	.40869	.69116	.42285	.73267	.43720	.77681	45
46	.89494	.65272	.40893	.69183	.42309	.73338	.43744	.77757	46
47	.89517	.65336	.40916	.69250	.42333	.73409	.43768	.77833	47
48	.89540	.65399	.40939	.69318	.42357	.73481	.43792	.77910	48
49	.89563	.65462	.40963	.69385	.42381	.73552	.43816	.77986	49
50	.89586	.65526	.40986	.69452	.42404	.73624	.43840	.78062	50
51	.89610	.65589	.41010	.69520	.42428	.73696	.43864	.78138	51
52	.89633	.65653	.41033	.69587	.42452	.73768	.43888	.78215	52
53	.89656	.65717	.41057	.69655	.42476	.73840	.43912	.78291	53
54	.89679	.65780	.41080	.69723	.42499	.73911	.43936	.78368	54
55	.89702	.65844	.41104	.69790	.42523	.73983	.43960	.78445	55
56	.89726	.65908	.41127	.69858	.42547	.74056	.43984	.78521	56
57	.89749	.65972	.41151	.69926	.42571	.74128	.44008	.78598	57
58	.89772	.66036	.41174	.69994	.42595	.74200	.44032	.78675	58
59	.89795	.66100	.41198	.70062	.42619	.74272	.44057	.78752	59
60	.89819	.66164	.41221	.70130	.42643	.74345	.44081	.78829	60

TABLE XIII.—VERSINES AND EXSECANTS.

	56°		57°		58°		59°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.44081	.78829	.45536	.83608	.47008	.88708	.48496	.94160	0
1	.44105	.78906	.45560	.83690	.47083	.88796	.48521	.94254	1
2	.44129	.78984	.45585	.83773	.47057	.88884	.48546	.94349	2
3	.44153	.79061	.45609	.83855	.47082	.88972	.48571	.94443	3
4	.44177	.79138	.45634	.83938	.47107	.89060	.48596	.94537	4
5	.44201	.79216	.45658	.84020	.47131	.89148	.48621	.94632	5
6	.44225	.79293	.45683	.84103	.47156	.89237	.48646	.94726	6
7	.44250	.79371	.45707	.84186	.47181	.89325	.48671	.94821	7
8	.44274	.79449	.45731	.84269	.47206	.89414	.48696	.94916	8
9	.44298	.79527	.45756	.84352	.47230	.89503	.48721	.95011	9
10	.44322	.79604	.45780	.84435	.47255	.89591	.48746	.95106	10
11	.44346	.79682	.45805	.84518	.47280	.89680	.48771	.95201	11
12	.44370	.79761	.45829	.84601	.47304	.89769	.48796	.95296	12
13	.44395	.79839	.45854	.84685	.47329	.89858	.48821	.95392	13
14	.44419	.79917	.45878	.84768	.47354	.89948	.48846	.95487	14
15	.44443	.79995	.45903	.84852	.47379	.90037	.48871	.95583	15
16	.44467	.80074	.45927	.84935	.47403	.90126	.48896	.95678	16
17	.44491	.80152	.45951	.85019	.47428	.90216	.48921	.95774	17
18	.44516	.80231	.45976	.85103	.47453	.90305	.48946	.95870	18
19	.44540	.80309	.46000	.85187	.47478	.90395	.48971	.95966	19
20	.44564	.80388	.46025	.85271	.47503	.90485	.48996	.96062	20
21	.44588	.80467	.46049	.85355	.47527	.90575	.49021	.96158	21
22	.44612	.80546	.46074	.85439	.47552	.90665	.49046	.96255	22
23	.44637	.80625	.46098	.85523	.47577	.90755	.49071	.96351	23
24	.44661	.80704	.46123	.85608	.47601	.90845	.49096	.96448	24
25	.44685	.80783	.46147	.85692	.47626	.90935	.49121	.96544	25
26	.44709	.80862	.46172	.85777	.47651	.91026	.49146	.96641	26
27	.44734	.80942	.46196	.85861	.47676	.91116	.49171	.96738	27
28	.44758	.81021	.46221	.85946	.47701	.91207	.49196	.96835	28
29	.44782	.81101	.46246	.86031	.47725	.91297	.49221	.96932	29
30	.44806	.81180	.46270	.86116	.47750	.91388	.49246	.97029	30
31	.44831	.81260	.46295	.86201	.47775	.91479	.49271	.97127	31
32	.44855	.81340	.46319	.86286	.47800	.91570	.49296	.97224	32
33	.44879	.81419	.46344	.86371	.47825	.91661	.49321	.97322	33
34	.44903	.81499	.46368	.86457	.47849	.91752	.49346	.97420	34
35	.44928	.81579	.46393	.86542	.47874	.91844	.49372	.97517	35
36	.44952	.81659	.46417	.86627	.47899	.91935	.49397	.97615	36
37	.44976	.81740	.46442	.86713	.47924	.92027	.49422	.97713	37
38	.45001	.81820	.46466	.86799	.47949	.92118	.49447	.97811	38
39	.45025	.81900	.46491	.86885	.47974	.92210	.49472	.97910	39
40	.45049	.81981	.46516	.86970	.47998	.92302	.49497	.98008	40
41	.45073	.82061	.46540	.87056	.48023	.92394	.49522	.98107	41
42	.45098	.82142	.46565	.87142	.48048	.92486	.49547	.98205	42
43	.45122	.82222	.46589	.87229	.48073	.92578	.49572	.98304	43
44	.45146	.82303	.46614	.87315	.48098	.92670	.49597	.98403	44
45	.45171	.82384	.46639	.87401	.48123	.92762	.49622	.98502	45
46	.45195	.82465	.46663	.87488	.48148	.92855	.49648	.98601	46
47	.45219	.82546	.46688	.87574	.48172	.92947	.49673	.98700	47
48	.45244	.82627	.46712	.87661	.48197	.93040	.49698	.98799	48
49	.45268	.82709	.46737	.87748	.48222	.93133	.49723	.98899	49
50	.45292	.82790	.46762	.87834	.48247	.93226	.49748	.98998	50
51	.45317	.82871	.46786	.87921	.48272	.93319	.49773	.99098	51
52	.45341	.82953	.46811	.88008	.48297	.93412	.49799	.99198	52
53	.45365	.83034	.46836	.88095	.48322	.93505	.49824	.99298	53
54	.45390	.83116	.46860	.88183	.48347	.93598	.49849	.99398	54
55	.45414	.83198	.46885	.88270	.48372	.93692	.49874	.99498	55
56	.45439	.83280	.46909	.88357	.48396	.93785	.49899	.99598	56
57	.45463	.83362	.46934	.88445	.48421	.93879	.49924	.99698	57
58	.45487	.83444	.46959	.88532	.48446	.93973	.49950	.99799	58
59	.45512	.83526	.46983	.88620	.48471	.94066	.49975	.99899	59
60	.45536	.83608	.47008	.88708	.48496	.94160	.50000	1.00000	60

TABLE XIII.—VERSINES AND EXSECANTS.

	60°		61°		62°		63°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.50000	1.00000	.51519	1.06267	.53053	1.13005	.54601	1.20269	0
1	.50025	1.00101	.51544	1.06375	.53079	1.13122	.54627	1.20395	1
2	.50050	1.00202	.51570	1.06483	.53104	1.13239	.54653	1.20521	2
3	.50076	1.00303	.51595	1.06592	.53130	1.13356	.54679	1.20647	3
4	.50101	1.00404	.51621	1.06701	.53156	1.13473	.54705	1.20773	4
5	.50126	1.00505	.51646	1.06809	.53181	1.13590	.54731	1.20900	5
6	.50151	1.00607	.51672	1.06918	.53207	1.13707	.54757	1.21026	6
7	.50176	1.00708	.51697	1.07027	.53233	1.13825	.54782	1.21153	7
8	.50202	1.00810	.51723	1.07137	.53258	1.13942	.54808	1.21280	8
9	.50227	1.00912	.51748	1.07246	.53284	1.14060	.54834	1.21407	9
10	.50252	1.01014	.51774	1.07356	.53310	1.14178	.54860	1.21535	10
11	.50277	1.01116	.51799	1.07465	.53336	1.14296	.54886	1.21662	11
12	.50303	1.01218	.51825	1.07575	.53361	1.14414	.54912	1.21790	12
13	.50328	1.01320	.51850	1.07685	.53387	1.14533	.54938	1.21918	13
14	.50353	1.01422	.51876	1.07795	.53413	1.14651	.54964	1.22045	14
15	.50378	1.01525	.51901	1.07905	.53439	1.14770	.54990	1.22174	15
16	.50404	1.01628	.51927	1.08015	.53464	1.14889	.55016	1.22302	16
17	.50429	1.01730	.51952	1.08126	.53490	1.15008	.55042	1.22430	17
18	.50454	1.01833	.51978	1.08236	.53516	1.15127	.55068	1.22559	18
19	.50479	1.01936	.52003	1.08347	.53542	1.15246	.55094	1.22688	19
20	.50505	1.02039	.52029	1.08458	.53567	1.15366	.55120	1.22817	20
21	.50530	1.02143	.52054	1.08569	.53593	1.15485	.55146	1.22946	21
22	.50555	1.02246	.52080	1.08680	.53619	1.15605	.55172	1.23075	22
23	.50581	1.02349	.52105	1.08791	.53645	1.15725	.55198	1.23205	23
24	.50606	1.02453	.52131	1.08903	.53670	1.15845	.55224	1.23334	24
25	.50631	1.02557	.52156	1.09014	.53696	1.15965	.55250	1.23464	25
26	.50656	1.02661	.52182	1.09126	.53722	1.16085	.55276	1.23594	26
27	.50682	1.02765	.52207	1.09238	.53748	1.16206	.55302	1.23724	27
28	.50707	1.02869	.52233	1.09350	.53774	1.16326	.55328	1.23855	28
29	.50732	1.02973	.52259	1.09462	.53799	1.16447	.55354	1.23985	29
30	.50758	1.03077	.52284	1.09574	.53825	1.16568	.55380	1.24116	30
31	.50783	1.03182	.52310	1.09686	.53851	1.16689	.55406	1.24247	31
32	.50808	1.03286	.52335	1.09799	.53877	1.16810	.55432	1.24378	32
33	.50834	1.03391	.52361	1.09911	.53903	1.16932	.55458	1.24509	33
34	.50859	1.03496	.52386	1.10024	.53928	1.17053	.55484	1.24640	34
35	.50884	1.03601	.52412	1.10137	.53954	1.17175	.55510	1.24772	35
36	.50910	1.03706	.52438	1.10250	.53980	1.17297	.55536	1.24903	36
37	.50935	1.03811	.52463	1.10363	.54006	1.17419	.55563	1.25035	37
38	.50960	1.03916	.52489	1.10477	.54032	1.17541	.55589	1.25167	38
39	.50986	1.04022	.52514	1.10590	.54058	1.17663	.55615	1.25300	39
40	.51011	1.04128	.52540	1.10704	.54083	1.17786	.55641	1.25432	40
41	.51036	1.04233	.52566	1.10817	.54109	1.17909	.55667	1.25565	41
42	.51062	1.04339	.52591	1.10931	.54135	1.18031	.55693	1.25697	42
43	.51087	1.04445	.52617	1.11045	.54161	1.18154	.55719	1.25830	43
44	.51113	1.04551	.52642	1.11159	.54187	1.18277	.55745	1.25963	44
45	.51138	1.04658	.52668	1.11274	.54213	1.18401	.55771	1.26097	45
46	.51163	1.04764	.52694	1.11388	.54238	1.18524	.55797	1.26230	46
47	.51189	1.04870	.52719	1.11503	.54264	1.18648	.55823	1.26364	47
48	.51214	1.04977	.52745	1.11617	.54290	1.18773	.55849	1.26498	48
49	.51239	1.05084	.52771	1.11732	.54316	1.18895	.55876	1.26632	49
50	.51265	1.05191	.52796	1.11847	.54342	1.19019	.55902	1.26766	50
51	.51290	1.05298	.52822	1.11963	.54368	1.19144	.55928	1.26900	51
52	.51316	1.05405	.52848	1.12078	.54394	1.19268	.55954	1.27035	52
53	.51341	1.05512	.52873	1.12193	.54420	1.19393	.55980	1.27169	53
54	.51366	1.05619	.52899	1.12309	.54446	1.19517	.56006	1.27304	54
55	.51392	1.05727	.52924	1.12425	.54471	1.19642	.56032	1.27439	55
56	.51417	1.05835	.52950	1.12540	.54497	1.19767	.56058	1.27574	56
57	.51443	1.05942	.52976	1.12657	.54523	1.19892	.56084	1.27710	57
58	.51468	1.06050	.53001	1.12773	.54549	1.20018	.56111	1.27845	58
59	.51494	1.06158	.53027	1.12889	.54575	1.20143	.56137	1.27981	59
60	.51519	1.06267	.53053	1.13005	.54601	1.20269	.56163	1.28117	60

TABLE XIII.—VERSINES AND EXSECANTS.

	64°		65°		66°		67°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.56163	1.28117	.57738	1.36620	.59326	1.45859	.60927	1.55930	0
1	.56189	1.28253	.57765	1.36768	.59353	1.46020	.60954	1.56106	1
2	.56215	1.28390	.57791	1.36916	.59379	1.46181	.60980	1.56282	2
3	.56241	1.28526	.57817	1.37064	.59406	1.46342	.61007	1.56458	3
4	.56267	1.28663	.57844	1.37212	.59433	1.46504	.61034	1.56634	4
5	.56294	1.28800	.57870	1.37361	.59459	1.46665	.61061	1.56811	5
6	.56320	1.28937	.57896	1.37509	.59486	1.46827	.61088	1.56988	6
7	.56346	1.29074	.57923	1.37658	.59512	1.46989	.61114	1.57165	7
8	.56372	1.29211	.57949	1.37808	.59539	1.47152	.61141	1.57342	8
9	.56398	1.29349	.57976	1.37957	.59566	1.47314	.61168	1.57520	9
10	.56425	1.29487	.58002	1.38107	.59592	1.47477	.61195	1.57698	10
11	.56451	1.29625	.58028	1.38256	.59619	1.47640	.61222	1.57876	11
12	.56477	1.29763	.58055	1.38406	.59645	1.47804	.61248	1.58054	12
13	.56503	1.29901	.58081	1.38556	.59672	1.47967	.61275	1.58233	13
14	.56529	1.30040	.58108	1.38707	.59699	1.48131	.61302	1.58412	14
15	.56555	1.30179	.58134	1.38857	.59725	1.48295	.61329	1.58591	15
16	.56582	1.30318	.58160	1.39008	.59752	1.48459	.61356	1.58771	16
17	.56608	1.30457	.58187	1.39159	.59779	1.48624	.61383	1.58950	17
18	.56634	1.30596	.58213	1.39311	.59805	1.48789	.61409	1.59130	18
19	.56660	1.30735	.58240	1.39462	.59832	1.48954	.61436	1.59311	19
20	.56687	1.30875	.58266	1.39614	.59859	1.49119	.61463	1.59491	20
21	.56713	1.31015	.58293	1.39766	.59885	1.49284	.61490	1.59672	21
22	.56739	1.31155	.58319	1.39918	.59912	1.49450	.61517	1.59853	22
23	.56765	1.31295	.58345	1.40070	.59938	1.49616	.61544	1.60035	23
24	.56791	1.31436	.58372	1.40222	.59965	1.49782	.61570	1.60217	24
25	.56818	1.31576	.58398	1.40375	.59992	1.49948	.61597	1.60399	25
26	.56844	1.31717	.58425	1.40528	.60018	1.50115	.61624	1.60581	26
27	.56870	1.31858	.58451	1.40681	.60045	1.50282	.61651	1.60763	27
28	.56896	1.31999	.58478	1.40835	.60072	1.50449	.61678	1.60946	28
29	.56923	1.32140	.58504	1.40988	.60098	1.50617	.61705	1.61129	29
30	.56949	1.32282	.58531	1.41142	.60125	1.50784	.61732	1.61313	30
31	.56975	1.32424	.58557	1.41296	.60152	1.50952	.61759	1.61496	31
32	.57001	1.32566	.58584	1.41450	.60178	1.51120	.61785	1.61680	32
33	.57028	1.32708	.58610	1.41605	.60205	1.51289	.61812	1.61864	33
34	.57054	1.32850	.58637	1.41760	.60232	1.51457	.61839	1.62049	34
35	.57080	1.32993	.58663	1.41914	.60259	1.51626	.61866	1.62234	35
36	.57106	1.33135	.58690	1.42070	.60285	1.51795	.61893	1.62419	36
37	.57133	1.33278	.58716	1.42225	.60312	1.51965	.61920	1.62604	37
38	.57159	1.33422	.58743	1.42380	.60339	1.52134	.61947	1.62790	38
39	.57185	1.33565	.58769	1.42536	.60365	1.52304	.61974	1.62976	39
40	.57212	1.33708	.58796	1.42692	.60392	1.52474	.62001	1.63162	40
41	.57238	1.33852	.58822	1.42848	.60419	1.52645	.62027	1.63348	41
42	.57264	1.33996	.58849	1.43005	.60445	1.52815	.62054	1.63535	42
43	.57291	1.34140	.58875	1.43162	.60472	1.52986	.62081	1.63722	43
44	.57317	1.34284	.58902	1.43318	.60499	1.53157	.62108	1.63909	44
45	.57343	1.34429	.58928	1.43476	.60526	1.53329	.62135	1.64097	45
46	.57369	1.34573	.58955	1.43633	.60552	1.53500	.62162	1.64285	46
47	.57396	1.34718	.58981	1.43790	.60579	1.53672	.62189	1.64473	47
48	.57422	1.34863	.59008	1.43948	.60606	1.53845	.62216	1.64662	48
49	.57448	1.35009	.59034	1.44106	.60633	1.54017	.62243	1.64851	49
50	.57475	1.35154	.59061	1.44264	.60659	1.54190	.62270	1.65040	50
51	.57501	1.35300	.59087	1.44423	.60686	1.54363	.62297	1.65229	51
52	.57527	1.35446	.59114	1.44582	.60713	1.54536	.62324	1.65419	52
53	.57554	1.35592	.59140	1.44741	.60740	1.54709	.62351	1.65609	53
54	.57580	1.35738	.59167	1.44900	.60766	1.54883	.62378	1.65799	54
55	.57606	1.35885	.59194	1.45059	.60793	1.55057	.62405	1.65989	55
56	.57633	1.36031	.59220	1.45219	.60820	1.55231	.62431	1.66180	56
57	.57659	1.36178	.59247	1.45378	.60847	1.55405	.62458	1.66371	57
58	.57685	1.36325	.59273	1.45539	.60873	1.55580	.62485	1.66563	58
59	.57712	1.36473	.59300	1.45699	.60900	1.55755	.62512	1.66755	59
60	.57738	1.36620	.59326	1.45859	.60927	1.55930	.62539	1.66947	60

TABLE XIII.—VERSINES AND EXSECANTS.

	68°		69°		70°		71°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.62539	1.66947	.64163	1.79043	.65798	1.92380	.67443	2.07155	0
1	.62566	1.67139	.64190	1.79254	.65825	1.92614	.67471	2.07415	1
2	.62593	1.67332	.64218	1.79466	.65853	1.92849	.67498	2.07675	2
3	.62620	1.67525	.64245	1.79679	.65880	1.93083	.67526	2.07936	3
4	.62647	1.67718	.64272	1.79891	.65907	1.93318	.67553	2.08197	4
5	.62674	1.67911	.64299	1.80104	.65935	1.93554	.67581	2.08459	5
6	.62701	1.68105	.64326	1.80318	.65962	1.93790	.67608	2.08721	6
7	.62728	1.68299	.64353	1.80531	.65989	1.94026	.67636	2.08983	7
8	.62755	1.68494	.64381	1.80746	.66017	1.94263	.67663	2.09246	8
9	.62782	1.68689	.64408	1.80960	.66044	1.94500	.67691	2.09510	9
10	.62809	1.68884	.64435	1.81175	.66071	1.94737	.67718	2.09774	10
11	.62836	1.69079	.64462	1.81390	.66099	1.94975	.67746	2.10038	11
12	.62863	1.69275	.64489	1.81605	.66126	1.95213	.67773	2.10303	12
13	.62890	1.69471	.64517	1.81821	.66154	1.95452	.67801	2.10568	13
14	.62917	1.69667	.64544	1.82037	.66181	1.95691	.67829	2.10834	14
15	.62944	1.69864	.64571	1.82254	.66208	1.95931	.67856	2.11101	15
16	.62971	1.70061	.64598	1.82471	.66236	1.96171	.67884	2.11367	16
17	.62998	1.70258	.64625	1.82688	.66263	1.96411	.67911	2.11635	17
18	.63025	1.70455	.64653	1.82906	.66290	1.96652	.67939	2.11903	18
19	.63052	1.70653	.64680	1.83124	.66318	1.96893	.67966	2.12171	19
20	.63079	1.70851	.64707	1.83342	.66345	1.97135	.67994	2.12440	20
21	.63106	1.71050	.64734	1.83561	.66373	1.97377	.68021	2.12709	21
22	.63133	1.71249	.64761	1.83780	.66400	1.97619	.68049	2.12979	22
23	.63161	1.71448	.64789	1.83999	.66427	1.97862	.68077	2.13249	23
24	.63188	1.71647	.64816	1.84219	.66455	1.98106	.68104	2.13520	24
25	.63215	1.71847	.64843	1.84439	.66482	1.98349	.68132	2.13791	25
26	.63242	1.72047	.64870	1.84659	.66510	1.98594	.68159	2.14063	26
27	.63269	1.72247	.64898	1.84880	.66537	1.98838	.68187	2.14335	27
28	.63296	1.72448	.64925	1.85102	.66564	1.99083	.68214	2.14608	28
29	.63323	1.72649	.64952	1.85323	.66592	1.99329	.68242	2.14881	29
30	.63350	1.72850	.64979	1.85545	.66619	1.99574	.68270	2.15155	30
31	.63377	1.73052	.65007	1.85767	.66647	1.99821	.68297	2.15429	31
32	.63404	1.73254	.65034	1.85990	.66674	2.00067	.68325	2.15704	32
33	.63431	1.73456	.65061	1.86213	.66702	2.00315	.68352	2.15979	33
34	.63458	1.73659	.65088	1.86437	.66729	2.00562	.68380	2.16255	34
35	.63485	1.73862	.65116	1.86661	.66756	2.00810	.68408	2.16531	35
36	.63512	1.74065	.65143	1.86885	.66784	2.01059	.68435	2.16806	36
37	.63539	1.74269	.65170	1.87109	.66811	2.01308	.68463	2.17083	37
38	.63566	1.74473	.65197	1.87334	.66839	2.01557	.68490	2.17363	38
39	.63594	1.74677	.65225	1.87560	.66866	2.01807	.68518	2.17641	39
40	.63621	1.74881	.65252	1.87785	.66894	2.02057	.68546	2.17920	40
41	.63648	1.75086	.65279	1.88011	.66921	2.02306	.68573	2.18199	41
42	.63675	1.75292	.65306	1.88238	.66949	2.02559	.68601	2.18479	42
43	.63702	1.75497	.65334	1.88465	.66976	2.02810	.68628	2.18759	43
44	.63729	1.75703	.65361	1.88692	.67003	2.03062	.68656	2.19040	44
45	.63756	1.75909	.65388	1.88920	.67031	2.03315	.68684	2.19322	45
46	.63783	1.76116	.65416	1.89148	.67058	2.03568	.68711	2.19604	46
47	.63810	1.76323	.65443	1.89376	.67086	2.03821	.68739	2.19886	47
48	.63838	1.76530	.65470	1.89605	.67113	2.04075	.68767	2.20169	48
49	.63865	1.76737	.65497	1.89834	.67141	2.04329	.68794	2.20453	49
50	.63892	1.76945	.65525	1.90063	.67168	2.04584	.68822	2.20737	50
51	.63919	1.77154	.65552	1.90293	.67196	2.04839	.68849	2.21021	51
52	.63946	1.77362	.65579	1.90524	.67223	2.05094	.68877	2.21306	52
53	.63973	1.77571	.65607	1.90754	.67251	2.05350	.68905	2.21592	53
54	.64000	1.77780	.65634	1.90986	.67278	2.05607	.68932	2.21878	54
55	.64027	1.77990	.65661	1.91217	.67306	2.05864	.68960	2.22165	55
56	.64055	1.78200	.65689	1.91449	.67333	2.06121	.68988	2.22452	56
57	.64082	1.78410	.65716	1.91681	.67361	2.06379	.69015	2.22740	57
58	.64109	1.78621	.65743	1.91914	.67388	2.06637	.69043	2.23028	58
59	.64136	1.78832	.65771	1.92147	.67416	2.06896	.69071	2.23317	59
60	.64163	1.79043	.65798	1.92380	.67443	2.07155	.69098	2.23607	60

TABLE XIII.—VERSINES AND EXSECANTS.

	72°		73°		74°		75°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.69098	2.23607	.70763	2.42030	.72436	2.62796	.74118	2.86370	0
1	.69126	2.23897	.70791	2.42356	.72464	2.63164	.74146	2.86790	1
2	.69154	2.24187	.70818	2.42683	.72492	2.63533	.74174	2.87211	2
3	.69181	2.24478	.70846	2.43010	.72520	2.63903	.74202	2.87633	3
4	.69209	2.24770	.70874	2.43337	.72548	2.64274	.74231	2.88056	4
5	.69237	2.25062	.70902	2.43666	.72576	2.64645	.74259	2.88479	5
6	.69264	2.25355	.70930	2.43995	.72604	2.65018	.74287	2.88904	6
7	.69292	2.25648	.70958	2.44324	.72632	2.65391	.74315	2.89330	7
8	.69320	2.25942	.70985	2.44655	.72660	2.65765	.74343	2.89756	8
9	.69347	2.26237	.71013	2.44986	.72688	2.66140	.74371	2.90184	9
10	.69375	2.26531	.71041	2.45317	.72716	2.66515	.74399	2.90613	10
11	.69403	2.26827	.71069	2.45650	.72744	2.66892	.74427	2.91042	11
12	.69430	2.27123	.71097	2.45983	.72772	2.67269	.74455	2.91473	12
13	.69458	2.27420	.71125	2.46316	.72800	2.67647	.74484	2.91904	13
14	.69486	2.27717	.71153	2.46651	.72828	2.68025	.74512	2.92337	14
15	.69514	2.28015	.71180	2.46986	.72856	2.68405	.74540	2.92770	15
16	.69541	2.28313	.71208	2.47321	.72884	2.68785	.74568	2.93204	16
17	.69569	2.28612	.71236	2.47658	.72912	2.69167	.74596	2.93640	17
18	.69597	2.28912	.71264	2.47995	.72940	2.69549	.74624	2.94076	18
19	.69624	2.29212	.71292	2.48333	.72968	2.69931	.74652	2.94514	19
20	.69652	2.29513	.71320	2.48671	.72996	2.70315	.74680	2.94950	20
21	.69680	2.29814	.71348	2.49010	.73024	2.70700	.74709	2.95392	21
22	.69708	2.30115	.71375	2.49350	.73052	2.71085	.74737	2.95832	22
23	.69735	2.30418	.71403	2.49691	.73080	2.71471	.74765	2.96274	23
24	.69763	2.30721	.71431	2.50032	.73108	2.71858	.74793	2.96716	24
25	.69791	2.31024	.71459	2.50374	.73136	2.72246	.74821	2.97160	25
26	.69818	2.31328	.71487	2.50716	.73164	2.72635	.74849	2.97604	26
27	.69846	2.31633	.71515	2.51060	.73192	2.73024	.74878	2.98050	27
28	.69874	2.31939	.71543	2.51404	.73220	2.73414	.74906	2.98497	28
29	.69902	2.32244	.71571	2.51748	.73248	2.73806	.74934	2.98944	29
30	.69929	2.32551	.71598	2.52094	.73276	2.74198	.74962	2.99393	30
31	.69957	2.32858	.71626	2.52440	.73304	2.74591	.74990	2.99843	31
32	.69985	2.33166	.71654	2.52787	.73332	2.74984	.75018	3.00293	32
33	.70013	2.33474	.71682	2.53134	.73360	2.75379	.75047	3.00745	33
34	.70040	2.33783	.71710	2.53482	.73388	2.75775	.75075	3.01198	34
35	.70068	2.34092	.71738	2.53831	.73416	2.76171	.75103	3.01652	35
36	.70096	2.34403	.71766	2.54181	.73444	2.76568	.75131	3.02107	36
37	.70124	2.34713	.71794	2.54531	.73472	2.76966	.75159	3.02563	37
38	.70151	2.35025	.71822	2.54883	.73500	2.77365	.75187	3.03020	38
39	.70179	2.35336	.71850	2.55235	.73528	2.77765	.75216	3.03479	39
40	.70207	2.35649	.71877	2.55587	.73557	2.78166	.75244	3.03938	40
41	.70235	2.35962	.71905	2.55940	.73585	2.78568	.75272	3.04398	41
42	.70263	2.36276	.71933	2.56294	.73613	2.78970	.75300	3.04860	42
43	.70290	2.36590	.71961	2.56649	.73641	2.79374	.75328	3.05322	43
44	.70318	2.36905	.71989	2.57005	.73669	2.79778	.75356	3.05786	44
45	.70346	2.37221	.72017	2.57361	.73697	2.80183	.75385	3.06251	45
46	.70374	2.37537	.72045	2.57718	.73725	2.80589	.75413	3.06717	46
47	.70401	2.37854	.72073	2.58076	.73753	2.80996	.75441	3.07184	47
48	.70429	2.38171	.72101	2.58434	.73781	2.81404	.75469	3.07652	48
49	.70457	2.38489	.72129	2.58794	.73809	2.81813	.75497	3.08121	49
50	.70485	2.38808	.72157	2.59154	.73837	2.82223	.75526	3.08591	50
51	.70513	2.39128	.72185	2.59514	.73865	2.82633	.75554	3.09063	51
52	.70540	2.39448	.72213	2.59876	.73893	2.83045	.75582	3.09535	52
53	.70568	2.39768	.72241	2.60238	.73921	2.83457	.75610	3.10009	53
54	.70596	2.40089	.72269	2.60601	.73950	2.83871	.75639	3.10484	54
55	.70624	2.40411	.72296	2.60965	.73978	2.84285	.75667	3.10960	55
56	.70652	2.40734	.72324	2.61330	.74006	2.84700	.75695	3.11437	56
57	.70679	2.41057	.72352	2.61695	.74034	2.85116	.75723	3.11915	57
58	.70707	2.41381	.72380	2.62061	.74062	2.85533	.75751	3.12394	58
59	.70735	2.41705	.72408	2.62428	.74090	2.85951	.75780	3.12875	59
60	.70763	2.42030	.72436	2.62796	.74118	2.86370	.75808	3.13357	60

TABLE XIII.—VERSINES AND EXSECANTS.

	76°		77°		78°		79°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.75808	3.13357	.77505	3.44541	.79209	3.80973	.80919	4.24084	0
1	.75836	3.13839	.77533	3.45102	.79237	3.81633	.80948	4.24870	1
2	.75864	3.14323	.77562	3.45664	.79266	3.82294	.80976	4.25658	2
3	.75892	3.14809	.77590	3.46228	.79294	3.82956	.81005	4.26448	3
4	.75921	3.15295	.77618	3.46793	.79323	3.83621	.81033	4.27241	4
5	.75949	3.15782	.77647	3.47360	.79351	3.84288	.81062	4.28036	5
6	.75977	3.16271	.77675	3.47928	.79380	3.84956	.81090	4.28833	6
7	.76005	3.16761	.77708	3.48498	.79408	3.85627	.81119	4.29634	7
8	.76034	3.17252	.77732	3.49069	.79437	3.86299	.81148	4.30436	8
9	.76062	3.17744	.77760	3.49642	.79465	3.86973	.81176	4.31241	9
10	.76090	3.18238	.77788	3.50216	.79493	3.87649	.81205	4.32049	10
11	.76118	3.18733	.77817	3.50791	.79522	3.88327	.81233	4.32859	11
12	.76147	3.19228	.77845	3.51368	.79550	3.89007	.81262	4.33671	12
13	.76175	3.19725	.77874	3.51947	.79579	3.89689	.81290	4.34486	13
14	.76203	3.20224	.77902	3.52527	.79607	3.90373	.81319	4.35304	14
15	.76231	3.20723	.77930	3.53109	.79636	3.91058	.81348	4.36124	15
16	.76260	3.21224	.77959	3.53692	.79664	3.91746	.81376	4.36947	16
17	.76288	3.21726	.77987	3.54277	.79693	3.92436	.81405	4.37772	17
18	.76316	3.22229	.78015	3.54863	.79721	3.93128	.81433	4.38600	18
19	.76344	3.22734	.78044	3.55451	.79750	3.93821	.81463	4.39437	19
20	.76373	3.23239	.78072	3.56041	.79778	3.94517	.81491	4.40263	20
21	.76401	3.23746	.78101	3.56632	.79807	3.95215	.81519	4.41099	21
22	.76429	3.24255	.78129	3.57224	.79835	3.95914	.81548	4.41937	22
23	.76458	3.24764	.78157	3.57819	.79864	3.96616	.81576	4.42778	23
24	.76486	3.25275	.78186	3.58414	.79892	3.97320	.81605	4.43622	24
25	.76514	3.25787	.78214	3.59012	.79921	3.98025	.81633	4.44468	25
26	.76542	3.26300	.78242	3.59611	.79949	3.98733	.81662	4.45317	26
27	.76571	3.26814	.78271	3.60211	.79978	3.99443	.81691	4.46169	27
28	.76599	3.27330	.78299	3.60813	.80006	4.00155	.81719	4.47023	28
29	.76627	3.27847	.78328	3.61417	.80035	4.00869	.81748	4.47881	29
30	.76655	3.28366	.78356	3.62023	.80063	4.01585	.81776	4.48740	30
31	.76684	3.28885	.78384	3.62630	.80092	4.02303	.81805	4.49603	31
32	.76712	3.29406	.78413	3.63238	.80120	4.03024	.81834	4.50468	32
33	.76740	3.29929	.78441	3.63849	.80149	4.03746	.81863	4.51337	33
34	.76769	3.30452	.78470	3.64461	.80177	4.04471	.81891	4.52208	34
35	.76797	3.30977	.78498	3.65074	.80206	4.05197	.81919	4.53081	35
36	.76825	3.31503	.78526	3.65690	.80234	4.05926	.81948	4.53958	36
37	.76854	3.32031	.78555	3.66307	.80263	4.06657	.81977	4.54837	37
38	.76882	3.32560	.78583	3.66925	.80291	4.07390	.82005	4.55720	38
39	.76910	3.33090	.78612	3.67545	.80320	4.08125	.82034	4.56605	39
40	.76938	3.33622	.78640	3.68167	.80348	4.08863	.82063	4.57493	40
41	.76967	3.34154	.78669	3.68791	.80377	4.09602	.82091	4.58383	41
42	.76995	3.34689	.78697	3.69417	.80405	4.10344	.82120	4.59277	42
43	.77023	3.35224	.78725	3.70044	.80434	4.11088	.82148	4.60174	43
44	.77052	3.35761	.78754	3.70673	.80462	4.11835	.82177	4.61073	44
45	.77080	3.36299	.78782	3.71303	.80491	4.12583	.82206	4.61976	45
46	.77108	3.36838	.78811	3.71935	.80520	4.13334	.82234	4.62881	46
47	.77137	3.37380	.78839	3.72569	.80548	4.14087	.82263	4.63790	47
48	.77165	3.37923	.78868	3.73205	.80577	4.14842	.82292	4.64701	48
49	.77193	3.38466	.78896	3.73843	.80605	4.15599	.82320	4.65616	49
50	.77222	3.39012	.78924	3.74482	.80634	4.16359	.82349	4.66533	50
51	.77250	3.39558	.78953	3.75123	.80663	4.17121	.82377	4.67454	51
52	.77278	3.40106	.78981	3.75766	.80691	4.17886	.82406	4.68377	52
53	.77307	3.40656	.79010	3.76411	.80719	4.18652	.82435	4.69304	53
54	.77335	3.41206	.79038	3.77057	.80748	4.19421	.82463	4.70234	54
55	.77363	3.41759	.79067	3.77705	.80776	4.20193	.82492	4.71166	55
56	.77392	3.42312	.79095	3.78355	.80805	4.20966	.82521	4.72102	56
57	.77420	3.42867	.79123	3.79007	.80833	4.21742	.82549	4.73041	57
58	.77448	3.43424	.79152	3.79661	.80862	4.22521	.82578	4.73983	58
59	.77477	3.43983	.79180	3.80316	.80891	4.23301	.82607	4.74929	59
60	.77505	3.44541	.79209	3.80973	.80919	4.24084	.82635	4.75877	60

TABLE XIII.—VERSINES AND EXSECANTS.

	80°		81°		82°		83°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.82635	4.75877	.84357	5.30245	.86083	6.18530	.87813	7.20551	0
1	.82664	4.76829	.84385	5.40422	.86112	6.20080	.87842	7.22500	1
2	.82692	4.77784	.84414	5.41002	.86140	6.21517	.87871	7.24457	2
3	.82721	4.78742	.84443	5.42787	.86169	6.23019	.87900	7.26425	3
4	.82750	4.79703	.84471	5.43977	.86198	6.24529	.87929	7.28402	4
5	.82778	4.80667	.84500	5.45171	.86227	6.26044	.87957	7.30388	5
6	.82807	4.81635	.84529	5.46369	.86256	6.27566	.87986	7.32384	6
7	.82836	4.82606	.84558	5.47572	.86284	6.29095	.88015	7.34390	7
8	.82864	4.83581	.84586	5.48779	.86313	6.30630	.88044	7.36405	8
9	.82893	4.84558	.84615	5.49991	.86342	6.32171	.88073	7.38431	9
10	.82922	4.85539	.84644	5.51206	.86371	6.33719	.88102	7.40466	10
11	.82950	4.86524	.84673	5.52429	.86400	6.35274	.88131	7.42511	11
12	.82979	4.87511	.84701	5.53655	.86428	6.36835	.88160	7.44566	12
13	.83008	4.88502	.84730	5.54886	.86457	6.38408	.88188	7.46632	13
14	.83036	4.89497	.84759	5.56121	.86486	6.39978	.88217	7.48707	14
15	.83065	4.90495	.84788	5.57361	.86515	6.41560	.88246	7.50793	15
16	.83094	4.91496	.84816	5.58606	.86544	6.43148	.88275	7.52889	16
17	.83122	4.92501	.84845	5.59855	.86573	6.44743	.88304	7.54996	17
18	.83151	4.93509	.84874	5.61110	.86601	6.46346	.88333	7.57113	18
19	.83180	4.94521	.84903	5.62369	.86630	6.47955	.88362	7.59241	19
20	.83208	4.95536	.84931	5.63633	.86659	6.49571	.88391	7.61379	20
21	.83237	4.96555	.84960	5.64902	.86688	6.51194	.88420	7.63528	21
22	.83266	4.97577	.84989	5.66176	.86717	6.52825	.88448	7.65688	22
23	.83294	4.98603	.85018	5.67454	.86746	6.54462	.88477	7.67859	23
24	.83323	4.99633	.85046	5.68738	.86774	6.56107	.88506	7.70041	24
25	.83352	5.00666	.85075	5.70027	.86803	6.57759	.88535	7.72224	25
26	.83380	5.01703	.85104	5.71321	.86832	6.59418	.88564	7.74438	26
27	.83409	5.02743	.85133	5.72620	.86861	6.61085	.88593	7.76653	27
28	.83438	5.03787	.85162	5.73924	.86890	6.62759	.88622	7.78880	28
29	.83467	5.04834	.85190	5.75233	.86919	6.64441	.88651	7.81118	29
30	.83495	5.05886	.85219	5.76547	.86947	6.66130	.88680	7.83367	30
31	.83524	5.06941	.85248	5.77866	.86976	6.67826	.88709	7.85628	31
32	.83553	5.08000	.85277	5.79191	.87005	6.69530	.88737	7.87901	32
33	.83581	5.09062	.85305	5.80521	.87034	6.71242	.88766	7.90186	33
34	.83610	5.10129	.85334	5.81856	.87063	6.72962	.88795	7.92482	34
35	.83639	5.11199	.85363	5.83196	.87092	6.74689	.88824	7.94791	35
36	.83667	5.12278	.85392	5.84543	.87120	6.76424	.88853	7.97111	36
37	.83696	5.13350	.85420	5.85893	.87149	6.78167	.88882	7.99444	37
38	.83725	5.14432	.85449	5.87250	.87178	6.79918	.88911	8.01788	38
39	.83754	5.15517	.85478	5.88612	.87207	6.81677	.88940	8.04146	39
40	.83782	5.16607	.85507	5.89979	.87236	6.83443	.88969	8.06515	40
41	.83811	5.17700	.85536	5.91352	.87265	6.85218	.88998	8.08897	41
42	.83840	5.18797	.85564	5.92731	.87294	6.87001	.89027	8.11292	42
43	.83868	5.19896	.85593	5.94115	.87323	6.88792	.89055	8.13699	43
44	.83897	5.21004	.85622	5.95505	.87351	6.90592	.89084	8.16120	44
45	.83926	5.22118	.85651	5.96900	.87380	6.92406	.89113	8.18553	45
46	.83954	5.23236	.85680	5.98301	.87409	6.94216	.89142	8.20999	46
47	.83983	5.24348	.85708	5.99708	.87438	6.96040	.89171	8.23459	47
48	.84012	5.25464	.85737	6.01120	.87467	6.97878	.89200	8.25931	48
49	.84041	5.26590	.85766	6.02538	.87496	6.99714	.89229	8.28417	49
50	.84069	5.27719	.85795	6.03962	.87524	7.01565	.89258	8.30917	50
51	.84098	5.28858	.85823	6.05392	.87553	7.03423	.89287	8.33430	51
52	.84127	5.29991	.85852	6.06828	.87582	7.05291	.89316	8.35957	52
53	.84155	5.31133	.85881	6.08269	.87611	7.07167	.89345	8.38497	53
54	.84184	5.32279	.85910	6.09717	.87640	7.09052	.89374	8.41052	54
55	.84213	5.33429	.85939	6.11171	.87669	7.10946	.89403	8.43620	55
56	.84242	5.34584	.85968	6.12630	.87698	7.12849	.89431	8.46203	56
57	.84270	5.35743	.85996	6.14096	.87726	7.14760	.89460	8.48800	57
58	.84299	5.36906	.86025	6.15568	.87755	7.16681	.89489	8.51411	58
59	.84328	5.38073	.86054	6.17046	.87784	7.18612	.89518	8.54037	59
60	.84357	5.39245	.86083	6.18530	.87813	7.20551	.89547	8.56677	60

TABLE XIII.—VERSINES AND EXSECANTS.

	84°		85°		86°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.89547	8.56677	.91284	10.47371	.93024	13.83559	0
1	.89576	8.59832	.91313	10.51199	.93053	13.89547	1
2	.89605	8.62002	.91342	10.55052	.93082	13.45586	2
3	.89634	8.64687	.91371	10.58982	.93111	13.51676	3
4	.89663	8.67387	.91400	10.62837	.93140	13.57817	4
5	.89692	8.70103	.91429	10.66769	.93169	13.64011	5
6	.89721	8.72833	.91458	10.70728	.93198	13.70258	6
7	.89750	8.75579	.91487	10.74714	.93227	13.76558	7
8	.89779	8.78341	.91516	10.78727	.93257	13.82913	8
9	.89808	8.81119	.91545	10.82768	.93286	13.89323	9
10	.89836	8.83912	.91574	10.86837	.93315	13.95788	10
11	.89865	8.86722	.91603	10.90934	.93344	14.02310	11
12	.89894	8.89547	.91632	10.95060	.93373	14.08890	12
13	.89923	8.92389	.91661	10.99214	.93402	14.15527	13
14	.89952	8.95248	.91690	11.03397	.93431	14.22223	14
15	.89981	8.98123	.91719	11.07610	.93460	14.28979	15
16	.90010	9.01015	.91748	11.11852	.93489	14.35795	16
17	.90039	9.03923	.91777	11.16125	.93518	14.42672	17
18	.90068	9.06849	.91806	11.20427	.93547	14.49611	18
19	.90097	9.09792	.91835	11.24761	.93576	14.56614	19
20	.90126	9.12752	.91864	11.29125	.93605	14.63679	20
21	.90155	9.15730	.91893	11.33521	.93634	14.70810	21
22	.90184	9.18725	.91922	11.37948	.93663	14.78005	22
23	.90213	9.21739	.91951	11.42408	.93692	14.85268	23
24	.90242	9.24770	.91980	11.46900	.93721	14.92597	24
25	.90271	9.27819	.92009	11.51424	.93750	14.99995	25
26	.90300	9.30887	.92038	11.55982	.93779	15.07462	26
27	.90329	9.33973	.92067	11.60572	.93808	15.14999	27
28	.90358	9.37077	.92096	11.65197	.93837	15.22607	28
29	.90386	9.40201	.92125	11.69856	.93866	15.30287	29
30	.90415	9.43343	.92154	11.74550	.93895	15.38041	30
31	.90444	9.46505	.92183	11.79278	.93924	15.45869	31
32	.90473	9.49685	.92212	11.84042	.93953	15.53772	32
33	.90502	9.52886	.92241	11.88841	.93982	15.61751	33
34	.90531	9.56106	.92270	11.93677	.94011	15.69808	34
35	.90560	9.59346	.92299	11.98549	.94040	15.77944	35
36	.90589	9.62605	.92328	12.03458	.94069	15.86159	36
37	.90618	9.65885	.92357	12.08404	.94098	15.94456	37
38	.90647	9.69186	.92386	12.13388	.94127	16.02835	38
39	.90676	9.72507	.92415	12.18411	.94156	16.11297	39
40	.90705	9.75849	.92444	12.23472	.94186	16.19843	40
41	.90734	9.79212	.92473	12.28572	.94215	16.28476	41
42	.90763	9.82596	.92502	12.33712	.94244	16.37196	42
43	.90792	9.86001	.92531	12.38891	.94273	16.46005	43
44	.90821	9.89428	.92560	12.44112	.94302	16.54908	44
45	.90850	9.92877	.92589	12.49373	.94331	16.63893	45
46	.90879	9.96348	.92618	12.54676	.94360	16.72975	46
47	.90908	9.99841	.92647	12.60021	.94389	16.82152	47
48	.90937	10.03356	.92676	12.65408	.94418	16.91424	48
49	.90966	10.06894	.92705	12.70838	.94447	17.00794	49
50	.90995	10.10455	.92734	12.76312	.94476	17.10262	50
51	.91024	10.14039	.92763	12.81829	.94505	17.19830	51
52	.91053	10.17646	.92792	12.87391	.94534	17.29501	52
53	.91082	10.21277	.92821	12.92999	.94563	17.39274	53
54	.91111	10.24932	.92850	12.98651	.94592	17.49153	54
55	.91140	10.28610	.92879	13.04350	.94621	17.59139	55
56	.91169	10.32313	.92908	13.10096	.94650	17.69233	56
57	.91197	10.36040	.92937	13.15889	.94679	17.79438	57
58	.91226	10.39792	.92966	13.21730	.94708	17.89755	58
59	.91255	10.43569	.92995	13.27620	.94737	18.00185	59
60	.91284	10.47371	.93024	13.33559	.94766	18.10732	60

TABLE XIII.—VERSINES AND EXSECANTS.

	87°		88°		89°		
	Vers.	Exsec.	Vers.	Exsec.	Vers.	Exsec.	
0	.94766	18.10732	.96510	27.65371	.98255	56.29869	0
1	.94795	18.21397	.96539	27.89440	.98284	57.26076	1
2	.94825	18.32182	.96568	28.13917	.98313	58.27431	2
3	.94854	18.43088	.96597	28.38812	.98342	59.31411	3
4	.94883	18.54119	.96626	28.64137	.98371	60.39105	4
5	.94912	18.65275	.96655	28.89903	.98400	61.50715	5
6	.94941	18.76560	.96684	29.16120	.98429	62.66460	6
7	.94970	18.87976	.96714	29.42802	.98458	63.86572	7
8	.94999	18.99524	.96743	29.69960	.98487	65.11304	8
9	.95028	19.11208	.96772	29.97607	.98517	66.40927	9
10	.95057	19.23028	.96801	30.25758	.98546	67.75736	10
11	.95086	19.34969	.96830	30.54425	.98575	69.16047	11
12	.95115	19.47093	.96859	30.83623	.98604	70.62285	12
13	.95144	19.59341	.96888	31.13366	.98633	72.14583	13
14	.95173	19.71737	.96917	31.43671	.98662	73.73586	14
15	.95202	19.84283	.96946	31.74554	.98691	75.39655	15
16	.95231	19.96982	.96975	32.06030	.98720	77.13274	16
17	.95260	20.09838	.97004	32.38118	.98749	78.94968	17
18	.95289	20.22852	.97033	32.70835	.98778	80.85315	18
19	.95318	20.36027	.97062	33.04199	.98807	82.84947	19
20	.95347	20.49368	.97092	33.38232	.98836	84.94561	20
21	.95377	20.62876	.97121	33.72952	.98866	87.14924	21
22	.95406	20.76555	.97150	34.08380	.98895	89.46886	22
23	.95435	20.90409	.97179	34.44539	.98924	91.91887	23
24	.95464	21.04440	.97208	34.81452	.98953	94.49471	24
25	.95493	21.18653	.97237	35.19141	.98982	97.22308	25
26	.95522	21.33050	.97266	35.57633	.99011	100.1119	26
27	.95551	21.47635	.97295	35.96953	.99040	103.1757	27
28	.95580	21.62413	.97324	36.37127	.99069	106.4311	28
29	.95609	21.77386	.97353	36.78185	.99098	109.8966	29
30	.95638	21.92559	.97382	37.20155	.99127	113.5930	30
31	.95667	22.07935	.97411	37.63068	.99156	117.5444	31
32	.95696	22.23520	.97440	38.06957	.99186	121.7780	32
33	.95725	22.39316	.97470	38.51855	.99215	126.3253	33
34	.95754	22.55329	.97499	38.97797	.99244	131.2223	34
35	.95783	22.71563	.97528	39.44820	.99273	136.5111	35
36	.95812	22.88022	.97557	39.92963	.99302	142.2406	36
37	.95842	23.04712	.97586	40.42266	.99331	148.4684	37
38	.95871	23.21637	.97615	40.92772	.99360	155.2623	38
39	.95900	23.38802	.97644	41.44525	.99389	162.7033	39
40	.95929	23.56212	.97673	41.97571	.99418	170.8883	40
41	.95958	23.73873	.97702	42.51961	.99447	179.9350	41
42	.95987	23.91790	.97731	43.07748	.99476	189.9668	42
43	.96016	24.09969	.97760	43.64980	.99505	201.2212	43
44	.96045	24.28414	.97789	44.23720	.99535	213.8600	44
45	.96074	24.47134	.97818	44.84026	.99564	228.1839	45
46	.96103	24.66133	.97848	45.45963	.99593	244.5540	46
47	.96132	24.85417	.97877	46.09596	.99623	263.4427	47
48	.96161	25.04994	.97906	46.74997	.99652	285.4795	48
49	.96190	25.24869	.97935	47.42241	.99680	311.5230	49
50	.96219	25.45051	.97964	48.11406	.99709	342.7752	50
51	.96248	25.65546	.97993	48.82576	.99738	380.9723	51
52	.96277	25.86360	.98022	49.55840	.99767	428.7187	52
53	.96307	26.07503	.98051	50.31290	.99796	490.1070	53
54	.96336	26.28981	.98080	51.09027	.99825	571.9581	54
55	.96365	26.50804	.98109	51.89156	.99855	686.5496	55
56	.96394	26.72978	.98138	52.71790	.99884	838.4369	56
57	.96423	26.95513	.98168	53.57046	.99913	1144.916	57
58	.96452	27.18417	.98197	54.45053	.99942	1717.874	58
59	.96481	27.41700	.98226	55.35946	.99971	3436.747	59
60	.96510	27.65371	.98255	56.29869	1.00000	Infinite	60

TABLE XIV.—CUBIC YARDS PER 100 FEET. SLOPES $\frac{1}{4}$: 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	45	53	60	68	82	90	97	105
2	93	107	122	137	167	181	196	211
3	142	163	186	208	253	275	297	319
4	193	223	252	281	341	370	400	430
5	245	283	319	356	431	468	505	542
6	300	344	389	433	522	567	611	656
7	356	408	460	512	616	668	719	771
8	415	474	533	593	711	770	830	889
9	475	542	608	675	808	875	942	1008
10	537	611	685	759	907	981	1056	1130
11	601	683	764	845	1008	1090	1171	1253
12	667	756	844	933	1111	1200	1289	1378
13	734	831	928	1023	1216	1312	1408	1505
14	804	907	1010	1115	1322	1426	1530	1633
15	875	986	1096	1208	1431	1542	1653	1764
16	948	1067	1184	1304	1541	1659	1778	1896
17	1023	1149	1274	1401	1653	1779	1905	2031
18	1100	1233	1366	1500	1767	1900	2033	2167
19	1179	1319	1460	1601	1883	2023	2164	2305
20	1259	1407	1555	1704	2000	2148	2296	2444
21	1342	1497	1653	1808	2119	2275	2431	2586
22	1426	1589	1752	1915	2241	2404	2567	2730
23	1512	1683	1853	2023	2364	2534	2705	2875
24	1600	1778	1955	2133	2489	2667	2844	3023
25	1690	1875	2060	2245	2616	2801	2986	3171
26	1781	1974	2166	2359	2744	2937	3130	3323
27	1875	2075	2274	2475	2875	3075	3275	3475
28	1970	2178	2384	2593	3007	3215	3423	3630
29	2068	2282	2496	2712	3142	3356	3571	3786
30	2167	2389	2610	2833	3278	3500	3722	3944
31	2268	2497	2726	2956	3416	3645	3875	4105
32	2370	2607	2844	3081	3556	3798	4030	4267
33	2475	2719	2964	3208	3697	3942	4186	4431
34	2581	2833	3085	3337	3841	4098	4344	4596
35	2690	2949	3208	3468	3986	4245	4505	4764
36	2800	3067	3333	3600	4133	4400	4667	4933
37	2912	3186	3460	3734	4282	4556	4831	5105
38	3026	3307	3589	3870	4433	4715	4996	5278
39	3142	3431	3719	4008	4586	4875	5164	5453
40	3259	3556	3852	4148	4741	5037	5333	5630
41	3379	3682	3986	4290	4897	5201	5505	5808
42	3500	3811	4122	4433	5056	5367	5678	5989
43	3623	3942	4260	4579	5216	5534	5853	6171
44	3748	4074	4400	4726	5378	5704	6030	6356
45	3875	4206	4541	4875	5542	5875	6208	6542
46	4004	4344	4684	5026	5707	6048	6389	6730
47	4134	4483	4830	5179	5875	6223	6571	6919
48	4267	4623	4978	5333	6044	6400	6756	7111
49	4401	4764	5127	5490	6216	6579	6942	7305
50	4537	4907	5278	5648	6389	6759	7130	7500
51	4675	5053	5430	5808	6564	6942	7319	7697
52	4815	5200	5584	5970	6741	7126	7511	7896
53	4956	5349	5741	6134	6919	7312	7705	8097
54	5100	5500	5900	6300	7100	7500	7900	8300
55	5245	5653	6060	6468	7282	7690	8097	8505
56	5393	5807	6222	6637	7467	7881	8296	8711
57	5542	5964	6386	6808	7653	8075	8497	8919
58	5693	6123	6552	6981	7841	8270	8700	9130
59	5845	6282	6719	7156	8031	8468	8905	9342
60	6000	6444	6889	7333	8222	8667	9111	9556

TABLE XIV.—CUBIC YARDS PER 100 FEET. SLOPES $\frac{1}{2}$: 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	46	54	61	69	83	91	98	106
2	96	111	126	141	170	185	200	215
3	150	172	194	217	261	283	306	328
4	207	237	267	296	356	385	415	444
5	269	306	343	380	454	491	528	565
6	333	378	422	467	556	600	644	689
7	402	454	506	557	661	713	765	817
8	474	533	593	652	770	830	889	948
9	550	617	683	750	883	950	1017	1083
10	630	704	778	852	1000	1074	1148	1222
11	713	794	876	957	1120	1202	1283	1365
12	800	889	978	1067	1244	1333	1422	1511
13	891	987	1083	1180	1372	1469	1565	1661
14	985	1089	1193	1296	1504	1607	1711	1815
15	1083	1194	1306	1417	1639	1750	1861	1972
16	1185	1304	1422	1541	1779	1896	2015	2133
17	1291	1417	1543	1669	1920	2046	2172	2298
18	1400	1533	1667	1800	2067	2200	2333	2467
19	1513	1654	1794	1935	2217	2357	2498	2639
20	1630	1778	1926	2074	2370	2519	2667	2815
21	1750	1906	2061	2217	2528	2683	2839	2994
22	1874	2037	2200	2363	2689	2852	3015	3178
23	2002	2172	2343	2513	2854	3024	3194	3365
24	2133	2311	2489	2667	3022	3200	3378	3556
25	2269	2454	2639	2824	3194	3380	3565	3750
26	2407	2600	2793	2985	3370	3563	3756	3948
27	2550	2750	2950	3150	3550	3750	3950	4151
28	2698	2904	3111	3319	3733	3941	4148	4356
29	2846	3061	3276	3491	3920	4135	4350	4565
30	3000	3222	3444	3667	4111	4333	4556	4778
31	3157	3387	3617	3846	4306	4535	4765	4994
32	3319	3556	3793	4030	4504	4741	4978	5215
33	3483	3728	3972	4217	4706	4950	5194	5439
34	3652	3904	4156	4407	4911	5163	5415	5667
35	3824	4083	4343	4602	5120	5380	5639	5898
36	4000	4267	4533	4800	5333	5600	5867	6133
37	4180	4454	4728	5002	5550	5824	6098	6372
38	4363	4644	4926	5207	5770	6052	6333	6615
39	4550	4839	5128	5417	5994	6283	6572	6861
40	4741	5037	5333	5630	6222	6519	6815	7111
41	4935	5239	5543	5846	6454	6757	7061	7365
42	5133	5444	5756	6067	6689	7000	7311	7622
43	5335	5654	5972	6291	6928	7246	7565	7883
44	5541	5867	6193	6519	7170	7496	7822	8148
45	5750	6083	6417	6750	7417	7750	8083	8417
46	5963	6304	6644	6985	7667	8007	8348	8689
47	6180	6528	6876	7224	7920	8269	8617	8965
48	6400	6756	7111	7467	8178	8533	8889	9244
49	6624	6987	7350	7713	8439	8802	9165	9528
50	6852	7222	7593	7963	8704	9074	9444	9815
51	7083	7461	7839	8217	8972	9350	9728	10106
52	7319	7704	8089	8474	9244	9630	10015	10400
53	7557	7950	8343	8735	9520	9913	10306	10698
54	7800	8200	8600	9000	9800	10200	10600	11000
55	8046	8454	8861	9269	10083	10491	10898	11306
56	8296	8711	9126	9541	10370	10785	11200	11615
57	8550	8972	9394	9817	10661	11083	11506	11928
58	8807	9237	9667	10096	10956	11385	11815	12244
59	9069	9506	9943	10380	11254	11691	12128	12565
60	9333	9778	10222	10667	11556	12000	12444	12889

TABLE XIV.—CUBIC YARDS PER 100 FEET. SLOPES 1 : 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 22	Base 30	Base 32
1	48	56	63	70	78	107	115	122
2	104	119	133	148	163	222	237	252
3	167	189	211	233	256	344	367	389
4	237	267	296	326	356	474	504	533
5	315	352	389	426	463	611	648	685
6	400	444	489	533	578	756	800	844
7	493	544	596	648	700	907	959	1011
8	593	652	711	770	830	1067	1126	1185
9	700	767	833	900	967	1233	1300	1367
10	815	889	963	1037	1111	1407	1481	1556
11	937	1019	1100	1181	1263	1589	1670	1752
12	1067	1156	1244	1333	1422	1778	1867	1956
13	1204	1300	1396	1493	1589	1974	2070	2167
14	1348	1452	1556	1659	1763	2178	2281	2385
15	1500	1611	1722	1833	1944	2389	2500	2611
16	1659	1778	1896	2015	2133	2607	2726	2844
17	1826	1952	2078	2204	2330	2833	2959	3085
18	2000	2133	2267	2400	2533	3067	3200	3333
19	2181	2322	2463	2604	2744	3307	3448	3589
20	2370	2519	2667	2815	2963	3556	3704	3852
21	2567	2722	2878	3033	3189	3811	3967	4122
22	2770	2933	3096	3259	3422	4074	4237	4404
23	2981	3152	3322	3493	3663	4344	4515	4685
24	3200	3378	3556	3733	3911	4622	4800	4978
25	3426	3611	3796	3981	4167	4907	5093	5278
26	3659	3852	4044	4237	4430	5200	5393	5585
27	3900	4100	4300	4500	4700	5500	5700	5900
28	4148	4356	4563	4770	4978	5807	6015	6222
29	4404	4619	4833	5048	5263	6122	6337	6552
30	4667	4889	5111	5333	5556	6444	6667	6889
31	4937	5167	5396	5626	5856	6774	7004	7233
32	5215	5452	5689	5926	6163	7111	7348	7585
33	5500	5744	5989	6233	6478	7456	7700	7944
34	5793	6044	6296	6548	6800	7807	8059	8311
35	6093	6352	6611	6870	7130	8167	8426	8685
36	6400	6667	6933	7200	7467	8533	8800	9067
37	6715	6989	7263	7537	7811	8907	9181	9456
38	7037	7319	7600	7881	8163	9289	9570	9852
39	7367	7656	7944	8233	8522	9678	9967	10256
40	7704	8000	8296	8593	8889	10074	10370	10667
41	8048	8352	8656	8959	9263	10478	10781	11085
42	8400	8711	9022	9333	9644	10889	11200	11511
43	8759	9078	9396	9715	10033	11307	11626	11944
44	9126	9452	9778	10104	10430	11733	12059	12385
45	9500	9833	10167	10500	10833	12167	12500	12833
46	9881	10222	10563	10904	11244	12607	12948	13289
47	10270	10619	10967	11315	11663	13056	13404	13752
48	10667	11022	11378	11733	12089	13511	13867	14222
49	11070	11433	11796	12159	12522	13974	14337	14700
50	11481	11852	12222	12593	12963	14444	14815	15185
51	11900	12278	12656	13033	13411	14922	15300	15678
52	12326	12711	13096	13481	13867	15407	15793	16178
53	12759	13152	13544	13937	14330	15900	16293	16685
54	13200	13600	14000	14400	14800	16400	16800	17200
55	13648	14056	14463	14870	15278	16907	17315	17722
56	14104	14519	14933	15348	15763	17422	17837	18252
57	14567	14989	15411	15833	16256	17944	18367	18789
58	15037	15467	15896	16326	16756	18474	18904	19333
59	15515	15952	16389	16826	17263	19011	19448	19885
60	16000	16444	16889	17333	17778	19556	20000	20444

TABLE XIV.—CUBIC YARDS PER 100 FEET. SLOPES $1\frac{1}{4}$: 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	50	57	65	72	80	109	117	124
2	111	126	141	156	170	230	244	259
3	183	206	228	250	272	361	383	406
4	267	296	326	356	385	504	533	563
5	361	398	435	472	509	657	694	731
6	467	511	556	600	644	822	867	911
7	583	635	687	739	791	998	1050	1102
8	711	770	830	889	948	1185	1244	1304
9	850	917	983	1050	1116	1383	1450	1517
10	1000	1074	1148	1222	1296	1598	1667	1741
11	1161	1243	1324	1406	1487	1813	1894	1976
12	1333	1422	1511	1600	1689	2044	2133	2222
13	1517	1613	1709	1806	1902	2287	2383	2480
14	1711	1815	1919	2022	2126	2541	2644	2749
15	1917	2028	2139	2250	2361	2806	2917	3028
16	2133	2252	2370	2489	2607	3081	3200	3319
17	2361	2487	2613	2739	2865	3369	3494	3620
18	2600	2733	2867	3000	3133	3667	3800	3933
19	2850	2991	3131	3272	3413	3976	4117	4257
20	3111	3259	3407	3556	3704	4296	4444	4592
21	3383	3539	3694	3850	4005	4628	4783	4939
22	3667	3830	3993	4156	4318	4970	5133	5296
23	3961	4131	4302	4472	4642	5324	5494	5665
24	4267	4444	4622	4800	4978	5689	5867	6044
25	4583	4769	4954	5139	5324	6065	6250	6435
26	4911	5104	5296	5489	5681	6452	6644	6837
27	5250	5450	5650	5850	6050	6850	7050	7250
28	5600	5807	6015	6222	6430	7259	7467	7674
29	5961	6176	6391	6606	6820	7680	7894	8109
30	6333	6556	6778	7000	7222	8111	8333	8555
31	6717	6946	7176	7406	7635	8554	8783	9013
32	7111	7348	7585	7822	8059	9007	9244	9482
33	7517	7761	8006	8250	8494	9472	9717	9962
34	7933	8185	8437	8689	8941	9948	10200	10452
35	8361	8620	8880	9139	9398	10435	10694	10954
36	8800	9067	9333	9600	9867	10933	11200	11467
37	9250	9524	9798	10072	10346	11443	11717	11991
38	9711	9993	10274	10556	10837	11963	12244	12526
39	10183	10472	10761	11050	11339	12494	12783	13072
40	10667	10963	11259	11556	11852	13037	13333	13630
41	11161	11465	11769	12072	12376	13591	13894	14198
42	11667	11978	12289	12600	12911	14156	14467	14778
43	12183	12502	12820	13139	13457	14731	15050	15369
44	12711	13037	13363	13689	14015	15319	15644	15970
45	13250	13583	13917	14250	14583	15917	16250	16583
46	13800	14141	14481	14822	15163	16526	16867	17207
47	14361	14709	15057	15406	15754	17146	17494	17843
48	14933	15289	15644	16000	16356	17778	18133	18489
49	15517	15880	16243	16606	16968	18420	18783	19146
50	16111	16481	16852	17222	17592	19074	19444	19815
51	16717	17094	17472	17850	18228	19739	20117	20494
52	17333	17719	18104	18489	18874	20415	20800	21185
53	17961	18354	18746	19139	19531	21102	21494	21887
54	18600	19000	19400	19800	20200	21800	22200	22600
55	19250	19657	20065	20472	20880	22509	22917	23324
56	19911	20326	20741	21156	21570	23230	23644	24059
57	20583	21006	21428	21850	22272	23961	24383	24805
58	21267	21696	22126	22556	22985	24704	25133	25563
59	21961	22396	22835	23272	23709	25457	25894	26332
60	22667	23111	23556	24000	24444	26222	26667	27111

TABLE XIV.—CUBIC YARDS PER 100 FEET. SLOPES 2 : 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 22	Base 24	Base 26
1	52	59	67	74	81	111	119	126
2	119	133	148	163	178	237	252	267
3	200	222	244	267	289	378	400	423
4	296	326	356	385	415	533	563	593
5	407	444	481	519	556	704	741	778
6	533	578	622	667	711	889	938	978
7	674	726	778	830	881	1089	1141	1193
8	830	880	948	1007	1067	1304	1363	1422
9	1000	1067	1133	1200	1267	1533	1600	1667
10	1185	1259	1333	1407	1481	1778	1853	1926
11	1385	1467	1548	1630	1711	2037	2119	2200
12	1600	1689	1778	1867	1956	2311	2400	2489
13	1830	1926	2022	2119	2215	2600	2696	2793
14	2074	2178	2281	2385	2489	2904	3007	3111
15	2333	2444	2556	2667	2778	3222	3333	3444
16	2607	2726	2844	2963	3081	3556	3674	3793
17	2896	3022	3148	3274	3400	3904	4030	4156
18	3200	3333	3467	3600	3733	4267	4400	4533
19	3519	3659	3800	3941	4081	4644	4785	4926
20	3853	4000	4148	4296	4444	5037	5185	5333
21	4200	4356	4511	4667	4822	5444	5600	5756
22	4563	4730	4899	5052	5215	5867	6030	6193
23	4941	5111	5281	5452	5622	6304	6474	6644
24	5333	5511	5689	5867	6044	6756	6933	7111
25	5741	5926	6111	6296	6481	7222	7407	7593
26	6163	6356	6548	6741	6933	7704	7896	8093
27	6600	6800	7000	7200	7400	8200	8400	8600
28	7053	7259	7467	7674	7881	8711	8919	9126
29	7519	7733	7948	8163	8378	9237	9452	9667
30	8000	8222	8444	8667	8889	9778	10000	10222
31	8496	8726	8956	9185	9415	10333	10563	10793
32	9007	9244	9481	9719	9956	10904	11141	11378
33	9533	9778	10022	10267	10511	11489	11733	11978
34	10074	10326	10578	10830	11081	12089	12341	12593
35	10630	10889	11148	11407	11667	12704	12963	13222
36	11200	11467	11733	12000	12267	13333	13600	13867
37	11785	12059	12333	12607	12881	13978	14252	14526
38	12385	12667	12948	13230	13511	14637	14919	15200
39	13000	13289	13578	13867	14156	15311	15600	15889
40	13630	13926	14222	14519	14815	16000	16296	16593
41	14274	14578	14881	15185	15489	16704	17007	17311
42	14933	15244	15556	15867	16178	17322	17733	18044
43	15607	15926	16244	16563	16881	18156	18474	18793
44	16296	16622	16948	17274	17600	18904	19220	19536
45	17000	17333	17667	18000	18333	19667	20000	20333
46	17719	18059	18400	18741	19081	20444	20785	21126
47	18452	18800	19148	19496	19844	21237	21585	21933
48	19200	19556	19911	20267	20622	22344	22700	23056
49	19963	20326	20689	21052	21415	22867	23230	23593
50	20741	20711	21481	21852	22222	23704	24074	24444
51	21533	21911	22289	22667	23044	24556	24933	25311
52	22341	22726	23111	23496	23881	25422	25807	26193
53	23163	23556	23948	24341	24733	26304	26696	27089
54	24000	24400	24800	25200	25600	27200	27600	28000
55	24852	25259	25667	26074	26481	28111	28519	28926
56	25719	26133	26548	26963	27378	29087	29452	29867
57	26600	27022	27444	27867	28289	29978	30400	30822
58	27496	27926	28356	28785	29215	30933	31363	31793
59	28407	28844	29281	29719	30156	31904	32341	32778
60	29333	29778	30222	30667	31111	32889	33333	33778

TABLE XIV.—CUBIC YARDS PER 100 FEET. SLOPES 3 : 1.

Depth	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	56	63	70	78	85	115	123	130
2	133	148	163	178	193	253	267	281
3	233	256	278	300	323	411	433	456
4	356	385	415	444	474	593	622	652
5	500	537	574	611	648	796	833	870
6	667	711	756	800	844	1023	1067	1111
7	856	907	959	1011	1063	1270	1322	1374
8	1067	1126	1185	1244	1304	1541	1600	1659
9	1300	1367	1433	1500	1567	1838	1900	1967
10	1556	1630	1704	1778	1853	2143	2223	2296
11	1833	1915	1996	2078	2159	2485	2567	2648
12	2133	2223	2311	2400	2489	2844	2933	3022
13	2456	2552	2648	2744	2841	3226	3322	3419
14	2800	2904	3007	3111	3215	3630	3733	3837
15	3167	3278	3389	3500	3611	4056	4167	4278
16	3556	3674	3793	3911	4030	4504	4623	4741
17	3967	4093	4219	4344	4470	4974	5100	5226
18	4400	4533	4667	4800	4933	5467	5600	5733
19	4856	4996	5137	5278	5419	5981	6122	6263
20	5333	5481	5630	5778	5926	6519	6667	6815
21	5833	5989	6144	6300	6456	7078	7233	7389
22	6356	6519	6681	6844	7007	7659	7822	7985
23	6900	7070	7241	7411	7581	8263	8433	8504
24	7467	7644	7822	8000	8178	8889	9067	9144
25	8056	8241	8426	8611	8796	9537	9722	9907
26	8667	8859	9052	9244	9437	10207	10400	10593
27	9300	9500	9700	9900	10100	10900	11100	11300
28	9956	10163	10370	10578	10785	11615	11822	12030
29	10633	10848	11063	11278	11493	12353	12567	12781
30	11333	11556	11778	12000	12223	13111	13333	13556
31	12056	12285	12515	12744	12974	13893	14123	14353
32	12800	13037	13274	13511	13748	14696	14933	15170
33	13567	13811	14056	14300	14544	15522	15767	16011
34	14356	14607	14859	15111	15363	16370	16622	16874
35	15167	15426	15685	15944	16204	17241	17500	17759
36	16000	16267	16533	16800	17067	18133	18400	18667
37	16856	17130	17404	17678	17952	19048	19322	19596
38	17733	18015	18296	18578	18859	19985	20267	20548
39	18633	18922	19211	19500	19789	20944	21233	21522
40	19556	19852	20148	20444	20741	21926	22223	22516
41	20500	20804	21107	21411	21715	22930	23233	23537
42	21467	21778	22089	22400	22711	23956	24267	24578
43	22456	22774	23093	23411	23730	25004	25322	25641
44	23467	23793	24119	24444	24770	26074	26400	26726
45	24500	24833	25167	25500	25833	27167	27500	27833
46	25556	25896	26237	26578	26919	28281	28622	28963
47	26633	26981	27330	27678	28026	29419	29767	30115
48	27733	28089	28444	28800	29156	30578	30933	31289
49	28856	29219	29581	29944	30307	31759	32122	32485
50	30000	30370	30741	31111	31481	32963	33333	33704
51	31167	31544	31922	32300	32678	34189	34567	34944
52	32356	32741	33126	33511	33896	35437	35822	36207
53	33567	33959	34352	34744	35137	36707	37100	37493
54	34800	35200	35600	36000	36400	38000	38400	38800
55	36056	36463	36870	37278	37685	39315	39722	40130
56	37333	37748	38163	38578	38993	40652	41067	41481
57	38633	39056	39478	39900	40322	42011	42433	42856
58	39956	40385	40815	41244	41674	43393	43822	44253
59	41300	41737	42174	42611	43048	44796	45233	45670
60	42667	43111	43556	44000	44444	46223	46667	47111

TABLE XV.—CUBIC YARDS IN 100 FEET LENGTH.

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
1	3.7	51	188.9	101	374.1	151	559.8	201	744.4
2	7.4	52	192.6	102	377.8	152	563.0	202	748.2
3	11.1	53	196.3	103	381.5	153	566.7	203	751.9
4	14.8	54	200.0	104	385.2	154	570.4	204	755.6
5	18.5	55	203.7	105	388.9	155	574.1	205	759.3
6	22.2	56	207.4	106	392.6	156	577.8	206	763.0
7	25.9	57	211.1	107	396.3	157	581.5	207	766.7
8	29.6	58	214.8	108	400.0	158	585.2	208	770.4
9	33.3	59	218.5	109	403.7	159	588.9	209	774.1
10	37.0	60	222.2	110	407.4	160	592.6	210	777.8
11	40.7	61	225.9	111	411.1	161	596.3	211	781.5
12	44.4	62	229.6	112	414.8	162	600.0	212	785.2
13	48.1	63	233.3	113	418.5	163	603.7	213	788.9
14	51.9	64	237.0	114	422.2	164	607.4	214	792.6
15	55.6	65	240.7	115	425.9	165	611.1	215	796.3
16	59.3	66	244.4	116	429.6	166	614.8	216	800.0
17	63.0	67	248.2	117	433.3	167	618.5	217	803.7
18	66.7	68	251.9	118	437.0	168	622.2	218	807.4
19	70.4	69	255.6	119	440.7	169	625.9	219	811.1
20	74.1	70	259.3	120	444.4	170	629.6	220	814.8
21	77.8	71	263.0	121	448.2	171	633.3	221	818.5
22	81.5	72	266.7	122	451.9	172	637.0	222	822.2
23	85.2	73	270.4	123	455.6	173	640.7	223	825.9
24	88.9	74	274.1	124	459.3	174	644.4	224	829.6
25	92.6	75	277.8	125	463.0	175	648.2	225	833.3
26	96.3	76	281.5	126	466.7	176	651.9	226	837.0
27	100.0	77	285.2	127	470.4	177	655.6	227	840.7
28	103.7	78	288.9	128	474.1	178	659.3	228	844.4
29	107.4	79	292.6	129	477.8	179	663.0	229	848.2
30	111.1	80	296.3	130	481.5	180	666.7	230	851.9
31	114.8	81	300.0	131	485.2	181	670.4	231	855.6
32	118.5	82	303.7	132	488.9	182	674.1	232	859.3
33	122.2	83	307.4	133	492.6	183	677.8	233	863.0
34	125.9	84	311.1	134	496.3	184	681.5	234	866.7
35	129.6	85	314.8	135	500.0	185	685.2	235	870.4
36	133.3	86	318.5	136	503.7	186	688.9	236	874.1
37	137.0	87	322.2	137	507.4	187	692.6	237	877.8
38	140.7	88	325.9	138	511.1	188	696.3	238	881.5
39	144.4	89	329.6	139	514.8	189	700.0	239	885.2
40	148.2	90	333.3	140	518.5	190	703.7	240	888.9
41	151.9	91	337.0	141	522.2	191	707.4	241	892.6
42	155.6	92	340.7	142	525.9	192	711.1	242	896.3
43	159.3	93	344.4	143	529.6	193	714.8	243	900.0
44	163.0	94	348.2	144	533.3	194	718.5	244	903.7
45	166.7	95	351.9	145	537.0	195	722.2	245	907.4
46	170.4	96	355.6	146	540.7	196	725.9	246	911.1
47	174.1	97	359.3	147	544.4	197	729.6	247	914.8
48	177.8	98	363.0	148	548.2	198	733.3	248	918.5
49	181.5	99	366.7	149	551.9	199	737.0	249	922.2
50	185.2	100	370.4	150	555.6	200	740.7	250	925.9

TABLE XV.—CUBIC YARDS IN 100 FEET LENGTH.

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
251	929.6	301	1114.8	351	1300.0	401	1485.2	451	1670.4
252	933.8	302	1118.5	352	1308.7	402	1488.9	452	1674.1
253	937.0	303	1122.2	353	1307.4	403	1492.6	453	1677.8
254	940.7	304	1125.9	354	1311.1	404	1496.3	454	1681.5
255	944.4	305	1129.6	355	1314.8	405	1500.0	455	1685.2
256	948.2	306	1133.3	356	1318.5	406	1503.7	456	1688.9
257	951.9	307	1137.0	357	1322.2	407	1507.4	457	1692.6
258	955.6	308	1140.7	358	1325.9	408	1511.1	458	1696.3
259	959.3	309	1144.4	359	1329.6	409	1514.8	459	1700.0
260	963.0	310	1148.2	360	1333.3	410	1518.5	460	1703.7
261	966.7	311	1151.9	361	1337.0	411	1522.2	461	1707.4
262	970.4	312	1155.6	362	1340.7	412	1525.9	462	1711.1
263	974.1	313	1159.3	363	1344.4	413	1529.6	463	1714.8
264	977.8	314	1163.0	364	1348.2	414	1533.3	464	1718.5
265	981.5	315	1166.7	365	1351.9	415	1537.0	465	1722.2
266	985.2	316	1170.4	366	1355.6	416	1540.7	466	1725.9
267	988.9	317	1174.1	367	1359.3	417	1544.4	467	1729.6
268	992.6	318	1177.8	368	1363.0	418	1548.2	468	1733.3
269	996.3	319	1181.5	369	1366.7	419	1551.9	469	1737.0
270	1000.0	320	1185.2	370	1370.4	420	1555.6	470	1740.7
271	1003.7	321	1188.9	371	1374.1	421	1559.3	471	1744.4
272	1007.4	322	1192.6	372	1377.8	422	1563.0	472	1748.2
273	1011.1	323	1196.3	373	1381.5	423	1566.7	473	1751.9
274	1014.8	324	1200.0	374	1385.2	424	1570.4	474	1755.6
275	1018.5	325	1203.7	375	1388.9	425	1574.1	475	1759.3
276	1022.2	326	1207.4	376	1392.6	426	1577.8	476	1763.0
277	1025.9	327	1211.1	377	1396.3	427	1581.5	477	1766.7
278	1029.6	328	1214.8	378	1400.0	428	1585.2	478	1770.4
279	1033.3	329	1218.5	379	1403.7	429	1588.9	479	1774.1
280	1037.0	330	1222.2	380	1407.4	430	1592.6	480	1777.8
281	1040.7	331	1225.9	381	1411.1	431	1596.3	481	1781.5
282	1044.4	332	1229.6	382	1414.8	432	1600.0	482	1785.2
283	1048.2	333	1233.3	383	1418.5	433	1603.7	483	1788.9
284	1051.9	334	1237.0	384	1422.2	434	1607.4	484	1792.6
285	1055.6	335	1240.7	385	1425.9	435	1611.1	485	1796.3
286	1059.3	336	1244.4	386	1429.6	436	1614.8	486	1800.0
287	1063.0	337	1248.2	387	1433.3	437	1618.5	487	1803.7
288	1066.7	338	1251.9	388	1437.0	438	1622.2	488	1807.4
289	1070.4	339	1255.6	389	1440.7	439	1625.9	489	1811.1
290	1074.1	340	1259.3	390	1444.4	440	1629.6	490	1814.8
291	1077.8	341	1263.0	391	1448.2	441	1633.3	491	1818.5
292	1081.5	342	1266.7	392	1451.9	442	1637.0	492	1822.2
293	1085.2	343	1270.4	393	1455.6	443	1640.7	493	1825.9
294	1088.9	344	1274.1	394	1459.3	444	1644.4	494	1829.6
295	1092.6	345	1277.8	395	1463.0	445	1648.2	495	1833.3
296	1096.3	346	1281.5	396	1466.7	446	1651.9	496	1837.0
297	1100.0	347	1285.2	397	1470.4	447	1655.6	497	1840.7
298	1103.7	348	1288.9	398	1474.1	448	1659.3	498	1844.4
299	1107.4	349	1292.6	399	1477.8	449	1663.0	499	1848.2
300	1111.1	350	1296.3	400	1481.5	450	1666.7	500	1851.9

TABLE XV.—CUBIC YARDS IN 100 FEET LENGTH.

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
501	1855.6	551	2040.7	601	2225.9	651	2411.1	701	2596.8
502	1859.3	552	2044.4	602	2229.6	652	2414.8	702	2600.0
503	1863.0	553	2048.2	603	2233.3	653	2418.5	703	2603.7
504	1866.7	554	2051.9	604	2237.0	654	2422.2	704	2607.4
505	1870.4	555	2055.6	605	2240.7	655	2425.9	705	2611.1
506	1874.1	556	2059.3	606	2244.4	656	2429.6	706	2614.8
507	1877.8	557	2063.0	607	2248.2	657	2433.3	707	2618.5
508	1881.5	558	2066.7	608	2251.9	658	2437.0	708	2622.2
509	1885.2	559	2070.4	609	2255.6	659	2440.7	709	2625.9
510	1888.9	560	2074.1	610	2259.3	660	2444.4	710	2629.6
511	1892.6	561	2077.8	611	2263.0	661	2448.2	711	2633.3
512	1896.3	562	2081.5	612	2266.7	662	2451.9	712	2637.0
513	1900.0	563	2085.2	613	2270.4	663	2455.6	713	2640.7
514	1903.7	564	2088.9	614	2274.1	664	2459.3	714	2644.4
515	1907.4	565	2092.6	615	2277.8	665	2463.0	715	2648.2
516	1911.1	566	2096.3	616	2281.5	666	2466.7	716	2651.9
517	1914.8	567	2100.0	617	2285.2	667	2470.4	717	2655.6
518	1918.5	568	2103.7	618	2288.9	668	2474.1	718	2659.3
519	1922.2	569	2107.4	619	2292.6	669	2477.8	719	2663.0
520	1925.9	570	2111.1	620	2296.3	670	2481.5	720	2666.7
521	1929.6	571	2114.8	621	2300.0	671	2485.2	721	2670.4
522	1933.3	572	2118.5	622	2303.7	672	2488.9	722	2674.1
523	1937.0	573	2122.2	623	2307.4	673	2492.6	723	2677.8
524	1940.7	574	2125.9	624	2311.1	674	2496.3	724	2681.5
525	1944.4	575	2129.6	625	2314.8	675	2500.0	725	2685.2
526	1948.2	576	2133.3	626	2318.5	676	2503.7	726	2688.9
527	1951.9	577	2137.0	627	2322.2	677	2507.4	727	2692.6
528	1955.6	578	2140.7	628	2325.9	678	2511.1	728	2696.3
529	1959.3	579	2144.4	629	2329.6	679	2514.8	729	2700.0
530	1963.0	580	2148.2	630	2333.3	680	2518.5	730	2703.7
531	1966.7	581	2151.9	631	2337.0	681	2522.2	731	2707.4
532	1970.4	582	2155.6	632	2340.7	682	2525.9	732	2711.1
533	1974.1	583	2159.3	633	2344.4	683	2529.6	733	2714.8
534	1977.8	584	2163.0	634	2348.2	684	2533.3	734	2718.5
535	1981.5	585	2166.7	635	2351.9	685	2537.0	735	2722.2
536	1985.2	586	2170.4	636	2355.6	686	2540.7	736	2725.9
537	1988.9	587	2174.1	637	2359.3	687	2544.4	737	2729.6
538	1992.6	588	2177.8	638	2363.0	688	2548.2	738	2733.3
539	1996.3	589	2181.5	639	2366.7	689	2551.9	739	2737.0
540	2000.0	590	2185.2	640	2370.4	690	2555.6	740	2740.7
541	2003.7	591	2188.9	641	2374.1	691	2559.3	741	2744.4
542	2007.4	592	2192.6	642	2377.8	692	2563.0	742	2748.2
543	2011.1	593	2196.3	643	2381.5	693	2566.7	743	2751.9
544	2014.8	594	2200.0	644	2385.2	694	2570.4	744	2755.6
545	2018.5	595	2203.7	645	2388.9	695	2574.1	745	2759.3
546	2022.2	596	2207.4	646	2392.6	696	2577.8	746	2763.0
547	2025.9	597	2211.1	647	2396.3	697	2581.5	747	2766.7
548	2029.6	598	2214.8	648	2400.0	698	2585.2	748	2770.4
549	2033.3	599	2218.5	649	2403.7	699	2588.9	749	2774.1
550	2037.0	600	2222.2	650	2407.4	700	2592.6	750	2777.8

TABLE XV.—CUBIC YARDS IN 100 FEET LENGTH.

Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.	Area. Sq. Ft.	Cubic Yards.
751	2781.5	801	2966.7	851	3151.9	901	3337.0	951	3522.2
752	2785.2	802	2970.4	852	3155.6	902	3340.7	952	3525.9
753	2788.9	803	2974.1	853	3159.3	903	3344.4	953	3529.6
754	2792.6	804	2977.8	854	3163.0	904	3348.2	954	3533.3
755	2796.3	805	2981.5	855	3166.7	905	3351.9	955	3537.0
756	2800.0	806	2985.2	856	3170.4	906	3355.6	956	3540.7
757	2803.7	807	2988.9	857	3174.1	907	3359.3	957	3544.4
758	2807.4	808	2992.6	858	3177.8	908	3363.0	958	3548.2
759	2811.1	809	2996.3	859	3181.5	909	3366.7	959	3551.9
760	2814.8	810	3000.0	860	3185.2	910	3370.4	960	3555.6
761	2818.5	811	3003.7	861	3188.9	911	3374.1	961	3559.3
762	2822.2	812	3007.4	862	3192.6	912	3377.8	962	3563.0
763	2825.9	813	3011.1	863	3196.3	913	3381.5	963	3566.7
764	2829.6	814	3014.8	864	3200.0	914	3385.2	964	3570.4
765	2833.3	815	3018.5	865	3203.7	915	3388.9	965	3574.1
766	2837.0	816	3022.2	866	3207.4	916	3392.6	966	3577.8
767	2840.7	817	3025.9	867	3211.1	917	3396.3	967	3581.5
768	2844.4	818	3029.6	868	3214.8	918	3400.0	968	3585.2
769	2848.2	819	3033.3	869	3218.5	919	3403.7	969	3588.9
770	2851.9	820	3037.0	870	3222.2	920	3407.4	970	3592.6
771	2855.6	821	3040.7	871	3225.9	921	3411.1	971	3596.3
772	2859.3	822	3044.4	872	3229.6	922	3414.8	972	3600.0
773	2863.0	823	3048.2	873	3233.3	923	3418.5	973	3603.7
774	2866.7	824	3051.9	874	3237.0	924	3422.2	974	3607.4
775	2870.4	825	3055.6	875	3240.7	925	3425.9	975	3611.1
776	2874.1	826	3059.3	876	3244.4	926	3429.6	976	3614.8
777	2877.8	827	3063.0	877	3248.2	927	3433.3	977	3618.5
778	2881.5	828	3066.7	878	3251.9	928	3437.0	978	3622.2
779	2885.2	829	3070.4	879	3255.6	929	3440.7	979	3625.9
780	2888.9	830	3074.1	880	3259.3	930	3444.4	980	3629.6
781	2892.6	831	3077.8	881	3263.0	931	3448.2	981	3633.3
782	2896.3	832	3081.5	882	3266.7	932	3451.9	982	3637.0
783	2900.0	833	3085.2	883	3270.4	933	3455.6	983	3640.7
784	2903.7	834	3088.9	884	3274.1	934	3459.3	984	3644.4
785	2907.4	835	3092.6	885	3277.8	935	3463.0	985	3648.2
786	2911.1	836	3096.3	886	3281.5	936	3466.7	986	3651.9
787	2914.8	837	3100.0	887	3285.2	937	3470.4	987	3655.6
788	2918.5	838	3103.7	888	3288.9	938	3474.1	988	3659.3
789	2922.2	839	3107.4	889	3292.6	939	3477.8	989	3663.0
790	2925.9	840	3111.1	890	3296.3	940	3481.5	990	3666.7
791	2929.6	841	3114.8	891	3300.0	941	3485.2	991	3670.4
792	2933.3	842	3118.5	892	3303.7	942	3488.9	992	3674.1
793	2937.0	843	3122.2	893	3307.4	943	3492.6	993	3677.8
794	2940.7	844	3125.9	894	3311.1	944	3496.3	994	3681.5
795	2944.4	845	3129.6	895	3314.8	945	3500.0	995	3685.2
796	2948.2	846	3133.3	896	3318.5	946	3503.7	996	3688.9
797	2951.9	847	3137.0	897	3322.2	947	3507.4	997	3692.6
798	2955.6	848	3140.7	898	3325.9	948	3511.1	998	3696.3
799	2959.3	849	3144.4	899	3329.6	949	3514.8	999	3700.0
800	2963.0	850	3148.2	900	3333.3	950	3518.5	1000	3703.7

TABLE XVI.

CONVERSION OF ENGLISH INCHES INTO CENTIMETRES.

Ins.	0	1	2	3	4	5	6	7	8	9
	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
0	0.000	2.540	5.080	7.620	10.16	12.70	15.24	17.78	20.32	22.86
10	25.40	27.94	30.48	33.02	35.56	38.10	40.64	43.18	45.72	48.26
20	50.80	53.34	55.88	58.42	60.96	63.50	66.04	68.58	71.12	73.66
30	76.20	78.74	81.28	83.82	86.36	88.90	91.44	93.98	96.52	99.06
40	101.60	104.14	106.68	109.22	111.76	114.30	116.84	119.38	121.92	124.46
50	127.00	129.54	132.08	134.62	137.16	139.70	142.24	144.78	147.32	149.86
60	152.40	154.94	157.48	160.02	162.56	165.10	167.64	170.18	172.72	175.26
70	177.80	180.34	182.88	185.42	187.96	190.50	193.04	195.58	198.12	200.66
80	203.20	205.74	208.28	210.82	213.36	215.90	218.44	220.98	223.52	226.06
90	228.60	231.14	233.68	236.22	238.76	241.30	243.84	246.38	248.92	251.46
100	254.00	256.54	259.08	261.62	264.16	266.70	269.24	271.78	274.32	276.86

CONVERSION OF CENTIMETRES INTO ENGLISH INCHES.

Cm.	0	1	2	3	4	5	6	7	8	9
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
0	0.000	0.394	0.787	1.181	1.575	1.969	2.362	2.756	3.150	3.543
10	3.937	4.331	4.724	5.118	5.512	5.906	6.299	6.693	7.087	7.480
20	7.874	8.268	8.662	9.055	9.449	9.843	10.236	10.630	11.024	11.418
30	11.811	12.205	12.599	12.992	13.386	13.780	14.173	14.567	14.961	15.355
40	15.748	16.142	16.536	16.929	17.323	17.717	18.111	18.504	18.898	19.292
50	19.685	20.079	20.473	20.867	21.260	21.654	22.048	22.441	22.835	23.229
60	23.622	24.016	24.410	24.804	25.197	25.591	25.985	26.378	26.772	27.166
70	27.560	27.953	28.347	28.741	29.134	29.528	29.922	30.316	30.709	31.103
80	31.497	31.890	32.284	32.678	33.071	33.465	33.859	34.253	34.646	35.040
90	35.434	35.827	36.221	36.615	37.009	37.402	37.796	38.190	38.583	38.977
100	39.370	39.764	40.158	40.552	40.945	41.339	41.733	42.126	42.520	42.914

CONVERSION OF ENGLISH FEET INTO METRES.

Feet.	0	1	2	3	4	5	6	7	8	9
	Met.	Met.	Met.	Met.	Met.	Met.	Met.	Met.	Met.	Met.
0	0.000	0.3048	0.6096	0.9144	1.2192	1.5239	1.8287	2.1335	2.4383	2.7431
10	3.0479	3.3527	3.6575	3.9623	4.2671	4.5719	4.8767	5.1815	5.4863	5.7911
20	6.0859	6.4006	6.7055	7.0102	7.3150	7.6198	7.9246	8.2294	8.5342	8.8390
30	9.1438	9.4486	9.7534	10.058	10.363	10.668	10.972	11.277	11.582	11.887
40	12.192	12.496	12.801	13.106	13.411	13.716	14.020	14.325	14.630	14.935
50	15.239	15.544	15.849	16.154	16.459	16.763	17.068	17.373	17.678	17.983
60	18.287	18.592	18.897	19.202	19.507	19.811	20.116	20.421	20.726	21.031
70	21.335	21.640	21.945	22.250	22.555	22.859	23.164	23.469	23.774	24.079
80	24.383	24.688	24.993	25.298	25.603	25.907	26.212	26.517	26.822	27.126
90	27.431	27.736	28.041	28.346	28.651	28.955	29.260	29.565	29.870	30.174
100	30.479	30.784	31.089	31.394	31.698	32.003	32.308	32.613	32.918	33.222

CONVERSION OF METRES INTO ENGLISH FEET.

Met.	0	1	2	3	4	5	6	7	8	9
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	0.000	3.2809	6.5618	9.8427	13.123	16.404	19.685	22.966	26.247	29.528
10	32.809	36.090	39.371	42.651	45.932	49.213	52.494	55.775	59.056	62.337
20	65.618	68.899	72.179	75.461	78.741	82.022	85.303	88.584	91.865	95.146
30	98.427	101.71	104.99	108.27	111.55	114.83	118.11	121.39	124.67	127.96
40	131.24	134.52	137.80	141.08	144.36	147.64	150.92	154.20	157.48	160.76
50	164.04	167.33	170.61	173.89	177.17	180.45	183.73	187.01	190.29	193.57
60	196.85	200.13	203.42	206.70	209.98	213.26	216.54	219.82	223.10	226.38
70	229.66	232.94	236.22	239.51	242.79	246.07	249.35	252.63	255.91	259.19
80	262.47	265.75	269.03	272.31	275.60	278.88	282.16	285.44	288.72	292.00
90	295.28	298.56	301.84	305.12	308.40	311.69	314.97	318.25	321.53	324.81
100	328.09	331.37	334.65	337.93	341.21	344.49	347.78	351.06	354.34	357.62

TABLE XVII.

CONVERSION OF ENGLISH STATUTE-MILES INTO KILOMETRES.

Miles.	0	1	2	3	4	5	6	7	8	9
	Kilo.	Kilo.	Kilo.	Kilo.	Kilo.	Kilo.	Kilo.	Kilo.	Kilo.	Kilo.
0	0.0000	1.6093	3.2186	4.8279	6.4372	8.0465	9.6558	11.2652	12.8745	14.4848
10	16.093	17.702	19.312	20.921	22.530	24.139	25.749	27.358	28.967	30.577
20	32.186	33.795	35.405	37.014	38.623	40.232	41.842	43.451	45.060	46.670
30	48.279	49.888	51.498	53.107	54.716	56.325	57.935	59.544	61.153	62.763
40	64.372	65.981	67.591	69.200	70.809	72.418	74.028	75.637	77.246	78.856
50	80.465	82.074	83.684	85.293	86.902	88.511	90.121	91.730	93.339	94.949
60	96.558	98.167	99.777	101.38	102.99	104.60	106.21	107.82	109.43	111.04
70	112.65	114.26	115.87	117.48	119.08	120.69	122.30	123.91	125.52	127.13
80	128.74	130.35	131.96	133.57	135.17	136.78	138.39	140.00	141.61	143.22
90	144.85	146.44	148.05	149.66	151.26	152.87	154.48	156.09	157.70	159.31
100	160.93	162.53	164.14	165.75	167.35	168.96	170.57	172.18	173.79	175.40

CONVERSION OF KILOMETRES INTO ENGLISH STATUTE-MILES.

Kilom.	0	1	2	3	4	5	6	7	8	9
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0	0.0000	0.6214	1.2427	1.8641	2.4855	3.1069	3.7282	4.3497	4.9711	5.5924
10	6.2138	6.8352	7.4565	8.0780	8.6994	9.3208	9.9421	10.562	11.185	11.805
20	12.427	13.049	13.670	14.292	14.913	15.534	16.156	16.776	17.399	18.019
30	18.641	19.263	19.884	20.506	21.127	21.748	22.370	22.990	23.613	24.233
40	24.855	25.477	26.098	26.720	27.341	27.962	28.584	29.204	29.827	30.447
50	31.069	31.690	32.311	32.933	33.554	34.175	34.797	35.417	36.040	36.660
60	37.282	37.904	38.525	39.147	39.768	40.389	41.011	41.631	42.254	42.874
70	43.497	44.118	44.739	45.361	45.982	46.603	47.225	47.845	48.468	49.088
80	49.711	50.332	50.953	51.575	52.196	52.817	53.439	54.059	54.682	55.302
90	55.924	56.545	57.166	57.788	58.409	59.030	59.652	60.272	60.895	61.515
100	62.138	62.759	63.380	64.002	64.623	65.244	65.866	66.486	67.109	67.729

TABLE XVIII.

LENGTH IN FEET OF 1' ARCS OF LATITUDE AND LONGITUDE.

Lat.	1' Lat.	1' Long.	Lat.	1' Lat.	1' Long.
1°	6045	6085	31°	6061	5222
2°	6045	6083	32°	6062	5166
3°	6045	6078	33°	6063	5109
4°	6045	6071	34°	6064	5051
5°	6045	6063	35°	6065	4991
6°	6045	6053	36°	6066	4930
7°	6046	6041	37°	6067	4867
8°	6046	6027	38°	6068	4802
9°	6046	6012	39°	6070	4736
10°	6047	5994	40°	6071	4669
11°	6047	5975	41°	6072	4600
12°	6048	5954	42°	6073	4530
13°	6048	5931	43°	6074	4458
14°	6049	5907	44°	6075	4385
15°	6049	5880	45°	6076	4311
16°	6050	5852	46°	6077	4235
17°	6050	5822	47°	6078	4158
18°	6051	5790	48°	6079	4080
19°	6052	5757	49°	6080	4001
20°	6052	5721	50°	6081	3920
21°	6053	5684	51°	6082	3838
22°	6054	5646	52°	6084	3755
23°	6054	5605	53°	6085	3671
24°	6055	5563	54°	6086	3586
25°	6056	5519	55°	6087	3499
26°	6057	5474	56°	6088	3413
27°	6058	5427	57°	6089	3323
28°	6059	5378	58°	6090	3233
29°	6060	5327	59°	6091	3142
30°	6061	5275	60°	6092	3051

EXAMPLE ILLUSTRATING USE OF TABLE XIX.

Find the horizontal distance and the difference of level when $\alpha = 16^\circ 30'$, $ak = 580$ feet, and the instrumental constant $c = .75$.

In column headed 16° opposite $30'$ in the series for "Horizontal

TABLE XIX.
SHOWING HORIZONTAL DISTANCES AND DIFFERENCES OF
LEVELS FOR STADIA MEASUREMENTS.

M.	0°.		1°		2°		3°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'....	100.00	.00	99.97	1.74	99.88	3.49	99.73	5.23
2'....	"	.06	"	1.80	99.87	3.55	99.72	5.28
4'....	"	.12	"	1.86	"	3.60	99.71	5.34
6'....	"	.17	99.96	1.92	"	3.66	"	5.40
8'....	"	.23	"	1.98	99.86	3.72	99.70	5.46
10'....	"	.29	"	2.04	"	3.78	99.69	5.52
12'....	"	.35	"	2.09	99.85	3.84	"	5.57
14'....	"	.41	99.95	2.15	"	3.90	99.68	5.63
16'....	"	.47	"	2.21	99.84	3.95	"	5.69
18'....	"	.52	"	2.27	"	4.01	99.67	5.75
20'....	"	.58	"	2.33	99.83	4.07	99.66	5.80
22'....	"	.64	99.94	2.38	"	4.13	"	5.86
24'....	"	.70	"	2.44	99.82	4.18	99.65	5.92
26'....	99.99	.76	"	2.50	"	4.24	99.64	5.98
28'....	"	.81	99.93	2.56	99.81	4.30	99.63	6.04
30'....	"	.87	"	2.62	"	4.36	"	6.09
32'....	"	.93	"	2.67	99.80	4.42	99.62	6.15
34'....	"	.99	"	2.73	"	4.48	"	6.21
36'....	"	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38'....	"	1.11	"	2.85	"	4.59	99.60	6.33
40'....	"	1.16	"	2.91	99.78	4.65	99.59	6.38
42'....	"	1.22	99.91	2.97	"	4.71	"	6.44
44'....	99.98	1.28	"	3.02	99.77	4.76	99.58	6.50
46'....	"	1.34	99.90	3.08	"	4.82	99.57	6.56
48'....	"	1.40	"	3.14	99.76	4.88	99.56	6.61
50'....	"	1.45	"	3.20	"	4.94	"	6.67
52'....	"	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54'....	"	1.57	"	3.31	99.74	5.05	99.54	6.78
56'....	99.97	1.63	"	3.37	"	5.11	99.53	6.84
58'....	"	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60'....	"	1.74	"	3.49	"	5.23	99.51	6.96
$c = .75$	.75	.01	.75	.02	.75	.03	.75	.05
$c = 1.00$	1.00	.01	1.00	.03	1.00	.04	1.00	.06
$c = 1.25$	1.25	.02	1.25	.03	1.25	.05	1.25	.08

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

Distances," we find 91.93 as the expression for $ak \cos^2 n$ when $ak = 100$; therefore, when $ak = 580$, $ak \cos^2 n = 91.93 \times 5.80 = 533.19$. Add to this $c \cos n$ from value of c at bottom of page, and we have $533.19 + .72 = 533.91$, hor. dist. Similarly, $27.23 \times 5.80 + .21 = 157.93$, diff. level.

TABLE XIX.
STADIA MEASUREMENTS.

M.	4°		5°		6°		7°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2'	"	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4'	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6'	99.49	7.18	99.21	8.85	98.87	10.57	98.47	12.26
8'	99.48	7.10	99.20	8.91	98.86	10.62	98.46	12.32
10'	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12'	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14'	"	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16'	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18'	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20'	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22'	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24'	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26'	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28'	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30'	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32'	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34'	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36'	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38'	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40'	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42'	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44'	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46'	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48'	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50'	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52'	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54'	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56'	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67
58'	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73
60'	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
$c = .75$	.75	.06	.75	.07	.75	.08	.74	.10
$c = 1.00$	1.00	.08	.99	.09	.99	.11	.99	.13
$c = 1.25$	1.25	.10	1.24	.11	1.24	.14	1.24	.16

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XIX.
STADIA MEASUREMENTS.

M.	8°		9°		10°		11°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2'	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4'	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6'	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8'	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10'	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12'	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14'	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16'	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18'	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20'	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22'	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.33
24'	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26'	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28'	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30'	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32'	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34'	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36'	97.76	14.79	97.23	16.44	96.62	18.08	95.96	19.70
38'	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40'	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42'	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44'	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46'	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48'	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50'	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52'	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54'	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56'	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58'	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60'	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34
c = .75	.74	.11	.74	.12	.74	.14	.73	.15
c = 1.00	.99	.15	.99	.16	.98	.18	.98	.20
c = 1.25	1.23	.18	1.23	.21	1.23	.23	1.22	.25

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XIX.
STADIA MEASUREMENTS.

M.	12°		13°		14°		15°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	95.68	20.84	94.94	21.92	94.15	23.47	93.80	25.00
2'	95.65	20.89	94.91	21.97	94.12	23.52	93.27	25.05
4'	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6'	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8'	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10'	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12'	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14'	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16'	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18'	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20'	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22'	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24'	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26'	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28'	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30'	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32'	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34'	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36'	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38'	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40'	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42'	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44'	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46'	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48'	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50'	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52'	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54'	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56'	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58'	94.97	21.87	94.17	23.43	93.33	24.95	92.43	26.45
60'	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
c=.75	.73	.16	.73	.17	.73	.19	.72	.20
c=1.00	.98	.22	.97	.23	.97	.25	.96	.27
c=1.25	1.22	.27	1.21	.20	1.21	.31	1.20	.34

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XIX.
STADIA MEASUREMENTS.

M.	16°		17°		18°		19°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'....	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2'....	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4'....	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
6'....	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8'....	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10'....	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12'....	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14'....	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
16'....	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18'....	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20'....	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
22'....	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24'....	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
26'....	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28'....	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30'....	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32'....	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34'....	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
36'....	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38'....	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40'....	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42'....	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44'....	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46'....	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48'....	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50'....	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52'....	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54'....	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
56'....	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58'....	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
60'....	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
c = .75	.72	.21	.72	.23	.71	.24	.71	.25
c = 1.00	.96	.28	.95	.30	.95	.32	.94	.33
c = 1.25	1.20	.36	1.19	.38	1.19	.40	1.18	.42

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XIX.
STADIA MEASUREMENTS.

M.	20°		21°		22°		23°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dis.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'....	88.80	82.14	87.16	83.46	85.97	84.73	84.73	85.97
2'....	88.26	82.18	87.12	83.50	85.93	84.77	84.69	86.01
4'....	88.23	82.23	87.08	83.51	85.89	84.82	84.65	86.05
6'....	88.19	82.27	87.04	83.59	85.85	84.86	84.61	86.09
8'....	88.15	82.32	87.00	83.63	85.80	84.90	84.57	86.13
10'....	88.11	82.36	86.96	83.67	85.76	84.94	84.52	86.17
12'....	88.08	82.41	86.92	83.72	85.72	84.98	84.48	86.21
14'....	88.04	82.45	86.88	83.76	85.68	85.02	84.44	86.25
16'....	88.00	82.49	86.84	83.80	85.64	85.07	84.40	86.29
18'....	87.96	82.54	86.80	83.84	85.60	85.11	84.35	86.33
20'....	87.93	82.58	86.77	83.89	85.56	85.15	84.31	86.37
22'....	87.89	82.63	86.73	83.93	85.52	85.19	84.27	86.41
24'....	87.85	82.67	86.69	83.97	85.48	85.23	84.23	86.45
26'....	87.81	82.71	86.65	84.01	85.44	85.27	84.18	86.49
28'....	87.77	82.76	86.61	84.06	85.40	85.31	84.14	86.53
30'....	87.74	82.80	86.57	84.10	85.36	85.36	84.10	86.57
32'....	87.70	82.85	86.53	84.14	85.31	85.40	84.06	86.61
34'....	87.66	82.89	86.49	84.18	85.27	85.44	84.01	86.65
36'....	87.63	82.93	86.45	84.23	85.23	85.48	83.97	86.69
38'....	87.58	82.98	86.41	84.27	85.19	85.52	83.93	86.73
40'....	87.54	83.02	86.37	84.31	85.15	85.56	83.89	86.77
42'....	87.51	83.07	86.33	84.35	85.11	85.60	83.84	86.80
44'....	87.47	83.11	86.29	84.40	85.07	85.64	83.80	86.84
46'....	87.43	83.15	86.25	84.44	85.02	85.68	83.76	86.88
48'....	87.39	83.20	86.21	84.48	84.98	85.72	83.72	86.92
50'....	87.35	83.24	86.17	84.52	84.94	85.76	83.67	86.96
52'....	87.31	83.28	86.13	84.57	84.90	85.80	83.63	87.00
54'....	87.27	83.33	86.09	84.61	84.86	85.85	83.59	87.04
56'....	87.24	83.37	86.05	84.65	84.82	85.89	83.54	87.08
58'....	87.20	83.41	86.01	84.69	84.77	85.93	83.50	87.12
60'....	87.16	83.46	85.97	84.73	84.73	85.97	83.46	87.16
c=.75	.70	.26	.70	.27	.69	.29	.69	.30
c=1.00	.94	.85	.93	.87	.92	.88	.92	.40
c=1.25	1.17	.41	1.16	.46	1.15	.48	1.15	.50

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XIX.
STADIA MEASUREMENTS.

M.	24°		25°		26°		27°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	88.46	87.16	82.14	88.80	80.78	89.40	79.89	40.45
2'	88.41	87.20	82.09	88.84	80.74	89.44	79.84	40.49
4'	88.37	87.23	82.05	88.88	80.69	89.47	79.80	40.53
6'	88.33	87.27	82.01	88.41	80.65	89.51	79.25	40.55
8'	88.28	87.31	81.96	88.45	80.60	89.54	79.20	40.59
10'	88.24	87.35	81.92	88.49	80.55	89.58	79.15	40.63
12'	88.20	87.39	81.87	88.53	80.51	89.61	79.11	40.66
14'	88.15	87.43	81.83	88.56	80.46	89.65	79.06	40.69
16'	88.11	87.47	81.78	88.60	80.41	89.69	79.01	40.72
18'	88.07	87.51	81.74	88.64	80.37	89.73	78.96	40.76
20'	88.02	87.54	81.69	88.67	80.32	89.76	78.92	40.79
22'	82.98	87.58	81.65	88.71	80.28	89.79	78.87	40.83
24'	82.93	87.62	81.60	88.75	80.23	89.83	78.82	40.86
26'	82.89	87.66	81.56	88.78	80.18	89.86	78.77	40.89
28'	82.85	87.70	81.51	88.82	80.14	89.90	78.73	40.92
30'	82.80	87.74	81.47	88.86	80.09	89.93	78.68	40.96
32'	82.76	87.77	81.42	88.89	80.04	89.97	78.63	40.99
34'	82.72	87.81	81.38	88.93	80.00	40.00	78.58	41.03
36'	82.67	87.85	81.33	88.97	79.95	40.04	78.54	41.06
38'	82.63	87.89	81.28	89.00	79.90	40.07	78.49	41.09
40'	82.58	87.93	81.24	89.04	79.86	40.11	78.44	41.13
42'	82.54	87.96	81.19	89.08	79.81	40.14	78.39	41.16
44'	82.49	88.00	81.15	89.11	79.76	40.18	78.34	41.19
46'	82.45	88.04	81.10	89.15	79.72	40.21	78.30	41.23
48'	82.41	88.08	81.06	89.18	79.67	40.24	78.25	41.26
50'	82.36	88.11	81.01	89.22	79.63	40.28	78.20	41.29
52'	82.32	88.15	80.97	89.26	79.58	40.31	78.15	41.33
54'	82.27	88.19	80.92	89.29	79.53	40.35	78.10	41.35
56'	82.23	88.23	80.87	89.33	79.48	40.38	78.06	41.39
58'	82.18	88.26	80.83	89.36	79.44	40.42	78.01	41.43
60'	82.14	88.30	80.78	89.40	79.39	40.45	77.96	41.45
$c=.75$	.68	.81	.68	.82	.67	.83	.66	.85
$c=1.00$	.91	.41	.90	.43	.89	.45	.89	.46
$c=1.25$	1.14	.52	1.13	.54	1.12	.56	1.11	.58

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XIX.
STADIA MEASUREMENTS.

M.	28°		29°		30°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	77.96	41.45	76.50	42.40	75.00	43.30
2'	77.91	41.48	76.45	42.43	74.95	43.33
4'	77.86	41.52	76.40	42.46	74.90	43.36
6'	77.81	41.55	76.35	42.49	74.85	43.39
8'	77.77	41.58	76.30	42.53	74.80	43.42
10'	77.72	41.61	76.25	42.56	74.75	43.45
12'	77.67	41.65	76.20	42.59	74.70	43.47
14'	77.63	41.68	76.15	42.62	74.65	43.50
16'	77.57	41.71	76.10	42.65	74.60	43.53
18'	77.53	41.74	76.05	42.68	74.55	43.56
20'	77.48	41.77	76.00	42.71	74.49	43.59
22'	77.43	41.81	75.95	42.74	74.44	43.62
24'	77.38	41.84	75.90	42.77	74.39	43.65
26'	77.33	41.87	75.85	42.80	74.34	43.67
28'	77.28	41.90	75.80	42.83	74.29	43.70
30'	77.23	41.93	75.75	42.86	74.24	43.73
32'	77.18	41.97	75.70	42.89	74.19	43.76
34'	77.13	42.00	75.65	42.92	74.14	43.79
36'	77.09	42.03	75.60	42.95	74.09	43.82
38'	77.04	42.06	75.55	42.98	74.04	43.84
40'	76.99	42.09	75.50	43.01	73.99	43.87
42'	76.94	42.12	75.45	43.04	73.93	43.90
44'	76.89	42.15	75.40	43.07	73.88	43.93
46'	76.84	42.19	75.35	43.10	73.83	43.95
48'	76.79	42.22	75.30	43.13	73.78	43.98
50'	76.74	42.25	75.25	43.16	73.73	44.01
52'	76.69	42.28	75.20	43.18	73.68	44.04
54'	76.64	42.31	75.15	43.21	73.63	44.07
56'	76.59	42.34	75.10	43.24	73.58	44.09
58'	76.55	42.37	75.05	43.27	73.52	44.12
60'	76.50	42.40	75.00	43.30	73.47	44.15
c=.75	.66	.86	.65	.87	.65	.88
c=1.00	.88	.48	.87	.49	.86	.51
c=1.25	1.10	.60	1.09	.62	1.08	.64

From Winslow's "Stadia Surveying." D. Van Nostrand's Science Series.

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	0°		1°		2°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	—∞	10.00000	8.24186	9.99993	8.54282	9.99974	60
1	6.46373	00000	24908	99993	54642	99973	59
2	76476	00000	25609	99993	54999	99973	58
3	94085	00000	26304	99993	55354	99972	57
4	7.03579	00000	26988	99992	55705	99972	56
5	16270	00000	27661	99992	56054	99971	55
6	24188	00000	28324	99992	56400	99971	54
7	30882	00000	28977	99992	56743	99970	53
8	36682	00000	29621	99992	57084	99970	52
9	41797	00000	30255	99991	57421	99969	51
10	7.46373	10.00000	8.30879	9.99991	8.57757	9.99969	50
11	50512	00000	31495	99991	58089	99968	49
12	54291	00000	32108	99990	58419	99968	48
13	57767	00000	32702	99990	58747	99967	47
14	60985	00000	33292	99990	59072	99967	46
15	63982	00000	33875	99990	59395	99967	45
16	66784	00000	34450	99989	59715	99966	44
17	69417	9.99999	35018	99989	60038	99966	43
18	71900	99999	35578	99989	60349	99965	42
19	74248	99999	36131	99989	60662	99964	41
20	7.76475	9.99999	8.36678	9.99988	8.60973	9.99964	40
21	78594	99999	37217	99988	61282	99963	39
22	80615	99999	37750	99988	61589	99963	38
23	82545	99999	38276	99987	61894	99962	37
24	84393	99999	38796	99987	62196	99962	36
25	86166	99999	39310	99987	62497	99961	35
26	87870	99999	39818	99986	62795	99961	34
27	89509	99999	40320	99986	63091	99960	33
28	91088	99999	40816	99986	63385	99960	32
29	92612	99998	41307	99985	63678	99959	31
30	7.94084	9.99998	8.41792	9.99985	8.63968	9.99959	30
31	95508	99998	42272	99985	64256	99958	29
32	96887	99998	42746	99984	64543	99958	28
33	98223	99998	43216	99984	64827	99957	27
34	99520	99998	43680	99984	65110	99956	26
35	8.00779	99998	44139	99983	65391	99956	25
36	02002	99998	44594	99983	65670	99955	24
37	03192	99997	45044	99983	65947	99955	23
38	04350	99997	45489	99982	66223	99954	22
39	05478	99997	45930	99982	66497	99954	21
40	8.06578	9.99997	8.46366	9.99982	8.66769	9.99958	20
41	07650	99997	46799	99981	67039	99952	19
42	08696	99997	47226	99981	67308	99952	18
43	09718	99997	47650	99981	67575	99951	17
44	10717	99996	48069	99980	67841	99951	16
45	11693	99996	48485	99980	68104	99950	15
46	12647	99996	48896	99979	68367	99949	14
47	13581	99996	49304	99979	68627	99949	13
48	14495	99996	49708	99979	68886	99948	12
49	15391	99996	50108	99978	69144	99948	11
50	8.16263	9.99995	8.50504	9.99978	8.69400	9.99947	10
51	17128	99995	50897	99977	69654	99946	9
52	17971	99995	51287	99977	69907	99946	8
53	18798	99995	51673	99977	70159	99945	7
54	19610	99995	52055	99976	70409	99944	6
55	20407	99994	52434	99976	70658	99944	5
56	21189	99994	52810	99975	70905	99943	4
57	21958	99994	53183	99975	71151	99942	3
58	22713	99994	53552	99974	71395	99942	2
59	23456	99994	53919	99974	71638	99941	1
60	24186	99993	54282	99974	71880	99940	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	89°		88°		87°		

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	3°		4°		5°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	8 71880	9.99940	8.84358	9.99894	8.94030	9.99834	60
1	72120	99940	84589	99898	94174	99833	59
2	72359	99939	84718	99892	94317	99832	58
3	72597	99938	84897	99891	94461	99831	57
4	72834	99938	85075	99891	94603	99830	56
5	73069	99937	85252	99890	94746	99829	55
6	73308	99936	85429	99889	94887	99828	54
7	73535	99936	85605	99888	95029	99827	53
8	73767	99935	85780	99887	95170	99825	52
9	73997	99934	85955	99886	95310	99824	51
10	8.74226	9.99934	8.86128	9.99885	8.95450	9.99823	50
11	74454	99933	86301	99884	95589	99822	49
12	74680	99932	86474	99883	95728	99821	48
13	74906	99932	86645	99882	95867	99820	47
14	75130	99931	86816	99881	96005	99819	46
15	75353	99930	86987	99880	96143	99817	45
16	75575	99929	87156	99879	96280	99816	44
17	75795	99929	87325	99879	96417	99815	43
18	76015	99928	87494	99878	96553	99814	42
19	76234	99927	87661	99877	96689	99813	41
20	8.76451	9.99926	8.87829	9.99876	8.96825	9.99812	40
21	76667	99926	87995	99875	96960	99810	39
22	76883	99925	88161	99874	97095	99809	38
23	77097	99924	88326	99873	97229	99808	37
24	77310	99923	88490	99872	97363	99807	36
25	77522	99923	88654	99871	97496	99806	35
26	77733	99922	88817	99870	97629	99804	34
27	77943	99921	88980	99869	97762	99803	33
28	78152	99920	89142	99868	97894	99802	32
29	78360	99920	89304	99867	98026	99801	31
30	8.78568	9.99919	8.89464	9.99866	8.98157	9.99800	30
31	78774	99918	89625	99865	98288	99798	29
32	78979	99917	89784	99864	98419	99797	28
33	79193	99917	89943	99863	98549	99796	27
34	79386	99916	90102	99862	98679	99795	26
35	79588	99915	90260	99861	98808	99793	25
36	79789	99914	90417	99860	98937	99792	24
37	79990	99913	90574	99859	99066	99791	23
38	80189	99913	90730	99858	99194	99790	22
39	80388	99912	90885	99857	99322	99788	21
40	8.80585	9.99911	8.91040	9.99856	8.99450	9.99787	20
41	80782	99910	91195	99855	99577	99786	19
42	80978	99909	91349	99854	99704	99785	18
43	81173	99909	91502	99853	99830	99783	17
44	81367	99908	91655	99852	99956	99782	16
45	81560	99907	91807	99851	9.00082	99781	15
46	81752	99906	91959	99850	00207	99780	14
47	81944	99905	92110	99848	00332	99778	13
48	82134	99904	92261	99847	00456	99777	12
49	82324	99904	92411	99846	00581	99776	11
50	8.82513	9.99903	8.92561	9.99845	9.00704	9.99775	10
51	82701	99902	92710	99844	00828	99773	9
52	82888	99901	92859	99843	00951	99772	8
53	83075	99900	93007	99842	01074	99771	7
54	83261	99899	93154	99841	01196	99769	6
55	83446	99898	93301	99840	01318	99768	5
56	83630	99898	93448	99839	01440	99767	4
57	83813	99897	93594	99838	01561	99765	3
58	83996	99896	93740	99837	01682	99764	2
59	84177	99895	93885	99836	01803	99763	1
60	84358	99894	94030	99834	01923	99761	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	86°		85°		84°		

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	6°		7°		8°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.01923	9.99761	9.08589	9.99675	9.14856	9.99575	60
1	02043	99760	08692	99674	14445	99574	59
2	02163	99759	08795	99672	14585	99572	58
3	02283	99757	08897	99670	14624	99570	57
4	02402	99756	08999	99669	14714	99568	56
5	02520	99755	09101	99667	14803	99566	55
6	02639	99753	09202	99666	14891	99565	54
7	02757	99752	09304	99664	14980	99563	53
8	02874	99751	09405	99663	15069	99561	52
9	02992	99749	09506	99661	15157	99559	51
10	9.03109	9.99748	9.09606	9.99659	9.15245	9.99557	50
11	03226	99747	09707	99658	15333	99556	49
12	03342	99745	09807	99656	15421	99554	48
13	03458	99744	09907	99655	15508	99552	47
14	03574	99742	10006	99653	15596	99550	46
15	03690	99741	10106	99651	15683	99548	45
16	03805	99740	10205	99650	15770	99546	44
17	03920	99738	10304	99648	15857	99545	43
18	04034	99737	10402	99647	15944	99543	42
19	04149	99736	10501	99645	16030	99541	41
20	9.04262	9.99734	9.10599	9.99643	9.16116	9.99539	40
21	04376	99733	10697	99642	16203	99537	39
22	04490	99731	10795	99640	16289	99535	38
23	04603	99730	10893	99638	16374	99533	37
24	04715	99728	10990	99637	16460	99532	36
25	04828	99727	11087	99635	16545	99530	35
26	04940	99726	11184	99633	16631	99528	34
27	05052	99724	11281	99632	16716	99526	33
28	05164	99723	11377	99630	16801	99524	32
29	05275	99721	11474	99629	16886	99522	31
30	9.05386	9.99720	9.11570	9.99627	9.16970	9.99520	30
31	05497	99718	11666	99625	17055	99518	29
32	05607	99717	11761	99624	17139	99517	28
33	05717	99716	11857	99622	17223	99515	27
34	05827	99714	11952	99620	17307	99513	26
35	05937	99713	12047	99619	17391	99511	25
36	06046	99711	12142	99617	17474	99509	24
37	06155	99710	12236	99615	17558	99507	23
38	06264	99708	12331	99613	17641	99505	22
39	06372	99707	12425	99612	17724	99503	21
40	9.06481	9.99705	9.12519	9.99610	9.17807	9.99501	20
41	06589	99704	12612	99608	17890	99499	19
42	06696	99702	12706	99607	17978	99497	18
43	06804	99701	12799	99605	18065	99496	17
44	06911	99699	12892	99603	18157	99494	16
45	07018	99698	12985	99601	18220	99492	15
46	07124	99696	13078	99600	18302	99490	14
47	07231	99695	13171	99598	18383	99488	13
48	07337	99693	13263	99596	18465	99486	12
49	07443	99692	13355	99595	18547	99484	11
50	9.07548	9.99690	9.13447	9.99593	9.18628	9.99482	10
51	07653	99689	13539	99591	18709	99480	9
52	07758	99687	13630	99589	18790	99478	8
53	07863	99686	13722	99588	18871	99476	7
54	07968	99684	13813	99586	18952	99474	6
55	08072	99683	13904	99584	19033	99472	5
56	08176	99681	13994	99582	19113	99470	4
57	08280	99680	14085	99581	19193	99468	3
58	08383	99678	14175	99579	19273	99466	2
59	08486	99677	14266	99577	19353	99464	1
60	08589	99675	14356	99575	19433	99462	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	88°		82°		81°		

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	9°		10°		11°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.19433	9.99463	9.23967	9.99335	9.28060	9.99196	60
1	19513	99460	24089	99333	28125	99192	59
2	19592	99458	24110	99331	28190	99190	58
3	19672	99456	24181	99328	28254	99187	57
4	19751	99454	24253	99326	28319	99185	56
5	19830	99452	24324	99324	28384	99183	55
6	19909	99450	24395	99322	28448	99180	54
7	19988	99448	24466	99319	28512	99177	53
8	20067	99446	24536	99317	28577	99175	52
9	20145	99444	24607	99315	28641	99172	51
10	9.20223	9.99442	9.24677	9.99313	9.28705	9.99170	50
11	20302	99440	24748	99310	28769	99167	49
12	20380	99438	24818	99308	28833	99165	48
13	20458	99436	24888	99306	28896	99162	47
14	20535	99434	24958	99304	28960	99160	46
15	20613	99432	25028	99301	29024	99157	45
16	20691	99429	25098	99299	29087	99155	44
17	20768	99427	25168	99297	29150	99152	43
18	20845	99425	25237	99294	29214	99150	42
19	20923	99423	25307	99292	29277	99147	41
20	9.20999	9.99421	9.25376	9.99290	9.29340	9.99145	40
21	21076	99419	25445	99288	29408	99142	39
22	21153	99417	25514	99285	29466	99140	38
23	21229	99415	25583	99283	29529	99137	37
24	21306	99413	25652	99281	29591	99135	36
25	21382	99411	25721	99278	29654	99132	35
26	21458	99409	25790	99276	29716	99130	34
27	21534	99407	25858	99274	29779	99127	33
28	21610	99404	25927	99271	29841	99124	32
29	21685	99402	25995	99269	29903	99122	31
30	9.21761	9.99400	9.26063	9.99267	9.29966	9.99119	30
31	21836	99398	26131	99264	30028	99117	29
32	21912	99396	26199	99262	30090	99114	28
33	21987	99394	26267	99260	30151	99112	27
34	22062	99392	26335	99257	30213	99109	26
35	22137	99390	26403	99255	30275	99106	25
36	22211	99388	26470	99253	30336	99104	24
37	22286	99385	26538	99250	30398	99101	23
38	22361	99383	26605	99248	30459	99099	22
39	22435	99381	26672	99245	30521	99096	21
40	9.22509	9.99379	9.26739	9.99243	9.30582	9.99098	20
41	22583	99377	26806	99241	30643	99091	19
42	22657	99375	26873	99238	30704	99088	18
43	22731	99372	26940	99236	30765	99086	17
44	22805	99370	27007	99233	30826	99083	16
45	22878	99368	27073	99231	30887	99080	15
46	22952	99366	27140	99229	30947	99078	14
47	23025	99364	27206	99226	31008	99075	13
48	23098	99362	27273	99224	31068	99072	12
49	23171	99359	27339	99221	31129	99070	11
50	9.23244	9.99357	9.27405	9.99219	9.31189	9.99067	10
51	23317	99355	27471	99217	31250	99064	9
52	23390	99353	27537	99214	31310	99062	8
53	23462	99351	27602	99212	31370	99059	7
54	23535	99348	27668	99209	31430	99056	6
55	23607	99346	27734	99207	31490	99054	5
56	23679	99344	27799	99204	31549	99051	4
57	23752	99342	27864	99202	31609	99048	3
58	23823	99340	27929	99200	31669	99046	2
59	23895	99337	27995	99197	31728	99043	1
60	23967	99335	28060	99195	31788	99040	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	80°		79°		78°		

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	12°		13°		14°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.31788	9.99040	9.35209	9.98872	9.38368	9.98690	60
1	31847	99038	35263	98869	38418	98687	59
2	31907	99035	35318	98867	38469	98684	58
3	31966	99032	35373	98864	38519	98681	57
4	32025	99030	35427	98861	38570	98678	56
5	32084	99027	35481	98858	38620	98675	55
6	32143	99024	35536	98855	38670	98671	54
7	32202	99022	35590	98852	38721	98668	53
8	32261	99019	35644	98849	38771	98665	52
9	32319	99016	35698	98846	38821	98662	51
10	9.32378	9.99013	9.35752	9.98843	9.38871	9.98659	50
11	32437	99011	35806	98840	38921	98656	49
12	32495	99008	35860	98837	38971	98652	48
13	32553	99005	35914	98834	39021	98649	47
14	32612	99002	35968	98831	39071	98646	46
15	32670	99000	36022	98828	39121	98643	45
16	32728	98997	36075	98825	39170	98640	44
17	32786	98994	36129	98822	39220	98636	43
18	32844	98991	36182	98819	39270	98633	42
19	32902	98989	36236	98816	39319	98630	41
20	9.32960	9.98986	9.36289	9.98813	9.39369	9.98627	40
21	33018	98983	36342	98810	39418	98623	39
22	33075	98980	36395	98807	39467	98620	38
23	33133	98978	36449	98804	39517	98617	37
24	33190	98975	36502	98801	39566	98614	36
25	33248	98972	36555	98798	39615	98610	35
26	33305	98969	36608	98795	39664	98607	34
27	33362	98967	36660	98792	39713	98604	33
28	33420	98964	36713	98789	39762	98601	32
29	33477	98961	36766	98786	39811	98597	31
30	9.33534	9.98958	9.36819	9.98783	9.39860	9.98594	30
31	33591	98955	36871	98780	39909	98591	29
32	33647	98953	36924	98777	39958	98588	28
33	33704	98950	36976	98774	40006	98584	27
34	33761	98947	37028	98771	40055	98581	26
35	33818	98944	37081	98768	40103	98578	25
36	33874	98941	37133	98765	40152	98574	24
37	33931	98938	37185	98762	40200	98571	23
38	33987	98936	37237	98759	40249	98568	22
39	34043	98933	37289	98756	40297	98565	21
40	9.34100	9.98930	9.37341	9.98753	9.40346	9.98561	20
41	34156	98927	37393	98750	40394	98558	19
42	34212	98924	37445	98746	40442	98555	18
43	34268	98921	37497	98743	40490	98551	17
44	34324	98919	37549	98740	40538	98548	16
45	34380	98916	37600	98737	40586	98545	15
46	34436	98913	37652	98734	40634	98541	14
47	34491	98910	37703	98731	40682	98538	13
48	34547	98907	37755	98728	40730	98535	12
49	34602	98904	37806	98725	40778	98531	11
50	9.34658	9.98901	9.37858	9.98722	9.40825	9.98528	10
51	34713	98898	37909	98719	40873	98525	9
52	34769	98896	37960	98715	40921	98521	8
53	34824	98893	38011	98712	40968	98518	7
54	34879	98890	38062	98709	41016	98515	6
55	34934	98887	38113	98706	41063	98511	5
56	34989	98884	38164	98703	41111	98508	4
57	35044	98881	38215	98700	41158	98505	3
58	35099	98878	38266	98697	41205	98501	2
59	35154	98875	38317	98694	41252	98498	1
60	35209	98872	38368	98690	41300	98494	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	77°		76°		75°		

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	15°		16°		17°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.41300	9.98494	9.44084	9.98284	9.46594	9.98060	60
1	41347	98491	44078	98281	46635	98056	59
2	41394	98488	44122	98277	46676	98052	58
3	41441	98484	44166	98273	46717	98048	57
4	41488	98481	44210	98270	46758	98044	56
5	41535	98477	44253	98266	46800	98040	55
6	41582	98474	44297	98262	46841	98036	54
7	41628	98471	44341	98259	46882	98032	53
8	41675	98467	44385	98255	46923	98029	52
9	41722	98464	44428	98251	46964	98025	51
10	9.41768	9.98460	9.44472	9.98248	9.47005	9.98021	50
11	41815	98457	44516	98244	47045	98017	49
12	41861	98453	44559	98240	47086	98013	48
13	41908	98450	44602	98237	47127	98009	47
14	41954	98447	44646	98233	47168	98005	46
15	42001	98443	44689	98229	47209	98001	45
16	42047	98440	44733	98226	47249	97997	44
17	42093	98436	44776	98222	47290	97993	43
18	42140	98433	44819	98218	47330	97989	42
19	42186	98429	44862	98215	47371	97986	41
20	9.42232	9.98426	9.44905	9.98211	9.47411	9.97982	40
21	42278	98422	44948	98207	47452	97978	39
22	42324	98419	44992	98204	47492	97974	38
23	42370	98415	45035	98200	47533	97970	37
24	42416	98412	45077	98196	47573	97966	36
25	42461	98409	45120	98192	47613	97962	35
26	42507	98405	45163	98189	47654	97958	34
27	42553	98402	45206	98185	47694	97954	33
28	42599	98398	45249	98181	47734	97950	32
29	42644	98395	45292	98177	47774	97946	31
30	9.42690	9.98391	9.45334	9.98174	9.47814	9.97942	30
31	42735	98388	45377	98170	47854	97938	29
32	42781	98384	45419	98166	47894	97934	28
33	42826	98381	45462	98162	47934	97930	27
34	42872	98377	45504	98159	47974	97926	26
35	42917	98373	45547	98155	48014	97922	25
36	42962	98370	45589	98151	48054	97918	24
37	43008	98366	45632	98147	48094	97914	23
38	43053	98363	45674	98144	48133	97910	22
39	43098	98359	45716	98140	48173	97906	21
40	9.43143	9.98356	9.45758	9.98136	9.48213	9.97902	20
41	43188	98352	45801	98132	48252	97898	19
42	43233	98349	45843	98129	48292	97894	18
43	43278	98345	45885	98125	48332	97890	17
44	43323	98342	45927	98121	48371	97886	16
45	43367	98338	45969	98117	48411	97882	15
46	43412	98334	46011	98113	48450	97878	14
47	43457	98331	46053	98110	48490	97874	13
48	43502	98327	46095	98106	48529	97870	12
49	43546	98324	46136	98102	48568	97866	11
50	9.43591	9.98320	9.46178	9.98098	9.48607	9.97861	10
51	43635	98317	46220	98094	48647	97857	9
52	43680	98313	46262	98090	48686	97853	8
53	43724	98309	46303	98087	48725	97849	7
54	43769	98306	46345	98083	48764	97845	6
55	43813	98302	46386	98079	48803	97841	5
56	43857	98299	46428	98075	48842	97837	4
57	43901	98295	46469	98071	48881	97833	3
58	43946	98291	46511	98067	48920	97829	2
59	43990	98288	46552	98063	48959	97825	1
60	44034	98284	46594	98060	48998	97821	0
	74°		78°		72°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	18°		19°		20°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.48998	9.97821	9.51264	9.97567	9.53405	9.97299	60
1	49037	97817	51301	97563	53440	97294	59
2	49076	97812	51338	97558	53475	97289	58
3	49115	97808	51374	97554	53509	97285	57
4	49153	97804	51411	97550	53544	97280	56
5	49192	97800	51447	97545	53578	97276	55
6	49231	97796	51484	97541	53613	97271	54
7	49269	97792	51520	97536	53647	97266	53
8	49308	97788	51557	97532	53682	97262	52
9	49347	97784	51593	97528	53716	97257	51
10	9.49385	9.97779	9.51629	9.97523	9.53751	9.97252	50
11	49424	97775	51666	97519	53785	97248	49
12	49462	97771	51702	97515	53819	97243	48
13	49500	97767	51738	97510	53854	97238	47
14	49539	97763	51774	97506	53888	97234	46
15	49577	97759	51811	97501	53923	97229	45
16	49615	97754	51847	97497	53957	97224	44
17	49654	97750	51883	97492	53991	97220	43
18	49692	97746	51919	97488	54025	97215	42
19	49730	97742	51955	97484	54059	97210	41
20	9.49768	9.97738	9.51991	9.97479	9.54093	9.97206	40
21	49806	97734	52027	97475	54127	97201	39
22	49844	97729	52063	97470	54161	97196	38
23	49882	97725	52099	97466	54195	97192	37
24	49920	97721	52135	97461	54229	97187	36
25	49958	97717	52171	97457	54263	97182	35
26	49996	97713	52207	97453	54297	97178	34
27	50034	97708	52242	97448	54331	97173	33
28	50072	97704	52278	97444	54365	97168	32
29	50110	97700	52314	97439	54399	97163	31
30	9.50148	9.97696	9.52350	9.97435	9.54433	9.97159	30
31	50185	97691	52385	97430	54466	97154	29
32	50223	97687	52421	97426	54500	97149	28
33	50261	97683	52456	97421	54534	97145	27
34	50298	97679	52492	97417	54567	97140	26
35	50336	97674	52527	97412	54601	97135	25
36	50374	97670	52563	97408	54635	97130	24
37	50411	97666	52598	97403	54668	97126	23
38	50449	97662	52634	97399	54702	97121	22
39	50486	97657	52669	97394	54735	97116	21
40	9.50523	9.97653	9.52705	9.97390	9.54769	9.97111	20
41	50561	97649	52740	97385	54802	97107	19
42	50599	97645	52775	97381	54836	97102	18
43	50635	97640	52811	97376	54869	97097	17
44	50673	97636	52846	97372	54903	97092	16
45	50710	97632	52881	97367	54936	97087	15
46	50747	97628	52916	97363	54969	97083	14
47	50784	97623	52951	97358	55003	97078	13
48	50821	97619	52986	97353	55036	97073	12
49	50858	97615	53021	97349	55069	97068	11
50	9.50896	9.97610	9.53056	9.97344	9.55102	9.97063	10
51	50933	97606	53092	97340	55136	97059	9
52	50970	97602	53126	97335	55169	97054	8
53	51007	97597	53161	97331	55202	97049	7
54	51043	97593	53196	97326	55235	97044	6
55	51080	97589	53231	97322	55268	97039	5
56	51117	97584	53266	97317	55301	97035	4
57	51154	97580	53301	97312	55334	97030	3
58	51191	97576	53336	97308	55367	97025	2
59	51227	97571	53370	97303	55400	97020	1
60	51264	97567	53405	97299	55433	97015	0
	71°		70°		69°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	21°		22°		23°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.55433	9.97015	9.57358	9.96717	9.59188	9.96403	60
1	55466	97010	57389	96711	59218	96397	59
2	55499	97005	57420	96706	59247	96392	58
3	55532	97001	57451	96701	59277	96387	57
4	55564	96996	57482	96696	59307	96381	56
5	55597	96991	57514	96691	59336	96376	55
6	55630	96986	57545	96686	59366	96370	54
7	55663	96981	57576	96681	59396	96365	53
8	55695	96976	57607	96676	59425	96360	52
9	55728	96971	57638	96670	59455	96354	51
10	9.55761	9.96966	9.57669	9.96665	9.59484	9.96349	50
11	55793	96962	57700	96660	59514	96343	49
12	55826	96957	57731	96655	59543	96338	48
13	55858	96952	57762	96650	59573	96333	47
14	55891	96947	57793	96645	59603	96327	46
15	55923	96942	57824	96640	59632	96322	45
16	55956	96937	57855	96634	59661	96316	44
17	55988	96932	57885	96629	59690	96311	43
18	56021	96927	57916	96624	59720	96305	42
19	56053	96922	57947	96619	59749	96300	41
20	9.56085	9.96917	9.57978	9.96614	9.59778	9.96294	40
21	56118	96913	58008	96608	59808	96289	39
22	56150	96907	58039	96603	59837	96284	38
23	56182	96903	58070	96598	59866	96278	37
24	56215	96898	58101	96593	59895	96273	36
25	56247	96893	58131	96588	59924	96267	35
26	56279	96888	58162	96583	59954	96262	34
27	56311	96883	58192	96577	59983	96256	33
28	56343	96878	58223	96572	60012	96251	32
29	56375	96873	58253	96567	60041	96245	31
30	9.56408	9.96868	9.58284	9.96562	9.60070	9.96240	30
31	56440	96863	58314	96556	60099	96234	29
32	56472	96858	58345	96551	60128	96229	28
33	56504	96853	58375	96546	60157	96223	27
34	56536	96848	58406	96541	60186	96218	26
35	56568	96843	58436	96535	60215	96212	25
36	56599	96838	58467	96530	60244	96207	24
37	56631	96833	58497	96525	60273	96201	23
38	56663	96828	58527	96520	60302	96196	22
39	56695	96823	58557	96514	60331	96190	21
40	9.56727	9.96818	9.58588	9.96509	9.60359	9.96185	20
41	56759	96813	58618	96504	60388	96179	19
42	56790	96808	58648	96498	60417	96174	18
43	56822	96803	58678	96493	60446	96168	17
44	56854	96798	58709	96488	60474	96162	16
45	56886	96793	58739	96483	60503	96157	15
46	56917	96788	58769	96477	60532	96151	14
47	56949	96783	58799	96472	60561	96146	13
48	56980	96778	58829	96467	60589	96140	12
49	57012	96772	58859	96461	60618	96135	11
50	9.57044	9.96767	9.58889	9.96456	9.60646	9.96129	10
51	57075	96762	58919	96451	60675	96123	9
52	57107	96757	58949	96445	60704	96118	8
53	57138	96752	58979	96440	60732	96112	7
54	57169	96747	59009	96435	60761	96107	6
55	57201	96742	59039	96429	60789	96101	5
56	57232	96737	59069	96424	60818	96095	4
57	57264	96732	59098	96419	60846	96090	3
58	57295	96727	59128	96413	60875	96084	2
59	57326	96722	59158	96408	60903	96079	1
60	57358	96717	59188	96403	60931	96073	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	
	68°		67°		66°		

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	24°		25°		26°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.60981	9.96073	9.62595	9.95728	9.64184	9.95866	60
1	60980	96067	62622	95722	64210	95860	59
2	60983	96062	62649	95716	64236	95854	58
3	61016	96056	62676	95710	64262	95848	57
4	61045	96050	62703	95704	64288	95841	56
5	61073	96045	62730	95698	64313	95835	55
6	61101	96039	62757	95692	64339	95829	54
7	61129	96034	62784	95686	64365	95823	53
8	61158	96028	62811	95680	64391	95817	52
9	61186	96022	62838	95674	64417	95810	51
10	9.61214	9.96017	9.62865	9.95668	9.64443	9.95804	50
11	61242	96011	62892	95663	64468	95798	49
12	61270	96005	62918	95657	64494	95792	48
13	61298	96000	62945	95651	64519	95786	47
14	61326	95994	62972	95645	64545	95779	46
15	61354	95988	62999	95639	64571	95773	45
16	61382	95982	63026	95633	64596	95767	44
17	61411	95977	63052	95627	64622	95761	43
18	61438	95971	63079	95621	64647	95754	42
19	61466	95965	63106	95615	64673	95748	41
20	9.61494	9.95960	9.63133	9.95609	9.64698	9.95742	40
21	61522	95954	63159	95603	64724	95736	39
22	61550	95948	63186	95597	64749	95729	38
23	61578	95942	63213	95591	64775	95723	37
24	61606	95937	63239	95585	64800	95717	36
25	61634	95931	63266	95579	64826	95711	35
26	61662	95925	63292	95573	64851	95704	34
27	61689	95920	63319	95567	64877	95198	33
28	61717	95914	63345	95561	64902	95192	32
29	61745	95908	63372	95555	64927	95185	31
30	9.61773	9.95902	9.63398	9.95549	9.64953	9.95179	30
31	61800	95897	63425	95543	64978	95173	29
32	61828	95891	63451	95537	65003	95167	28
33	61856	95885	63478	95531	65029	95160	27
34	61883	95879	63504	95525	65054	95154	26
35	61911	95873	63531	95519	65079	95148	25
36	61939	95868	63557	95513	65104	95141	24
37	61966	95862	63583	95507	65130	95135	23
38	61994	95856	63610	95500	65155	95129	22
39	62021	95850	63636	95494	65180	95123	21
40	9.62049	9.95844	9.63662	9.95488	9.65205	9.95116	20
41	62076	95839	63689	95482	65230	95110	19
42	62104	95833	63715	95476	65255	95103	18
43	62131	95827	63741	95470	65281	95097	17
44	62159	95821	63767	95464	65306	95090	16
45	62186	95815	63794	95458	65331	95084	15
46	62214	95810	63820	95452	65356	95078	14
47	62241	95804	63846	95446	65381	95071	13
48	62268	95798	63872	95440	65406	95065	12
49	62296	95792	63898	95434	65431	95059	11
50	9.62323	9.95786	9.63924	9.95427	9.65456	9.95052	10
51	62350	95780	63950	95421	65481	95046	9
52	62377	95775	63976	95415	65506	95039	8
53	62405	95769	64002	95409	65531	95033	7
54	62432	95763	64028	95403	65556	95027	6
55	62459	95757	64054	95397	65580	95020	5
56	62486	95751	64080	95391	65605	95014	4
57	62513	95745	64106	95384	65630	95007	3
58	62541	95739	64132	95378	65655	95001	2
59	62568	95733	64158	95372	65680	94995	1
60	62595	95728	64184	95366	65705	94988	0
	65°		64°		63°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	27°		28°		29°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.65705	9.94988	9.67161	9.94598	9.68557	9.94182	60
1	65729	94982	67186	94587	68580	94175	59
2	65754	94975	67208	94580	68603	94168	58
3	65779	94969	67232	94573	68625	94161	57
4	65804	94962	67256	94567	68648	94154	56
5	65828	94956	67280	94560	68671	94147	55
6	65853	94949	67303	94553	68694	94140	54
7	65878	94943	67327	94546	68716	94133	53
8	65902	94936	67350	94540	68739	94126	52
9	65927	94930	67374	94533	68762	94119	51
10	9.65952	9.94923	9.67398	9.94526	9.68784	9.94112	50
11	65976	94917	67421	94519	68807	94105	49
12	66001	94911	67445	94513	68829	94098	48
13	66025	94904	67468	94506	68852	94090	47
14	66050	94898	67492	94499	68875	94083	46
15	66075	94891	67515	94492	68897	94076	45
16	66099	94885	67539	94485	68920	94069	44
17	66124	94878	67562	94477	68942	94062	43
18	66148	94871	67586	94472	68965	94055	42
19	66173	94865	67609	94465	68987	94048	41
20	9.66197	9.94858	9.67633	9.94458	9.69010	9.94041	40
21	66221	94852	67656	94451	69032	94034	39
22	66246	94845	67680	94445	69055	94027	38
23	66270	94839	67703	94438	69077	94020	37
24	66295	94832	67726	94431	69100	94012	36
25	66319	94826	67750	94424	69122	94005	35
26	66343	94819	67773	94417	69144	93998	34
27	66368	94813	67796	94410	69167	93991	33
28	66392	94806	67820	94404	69189	93984	32
29	66416	94799	67843	94397	69212	93977	31
30	9.66441	9.94793	9.67866	9.94390	9.69234	9.93970	30
31	66465	94786	67890	94383	69256	93963	29
32	66489	94780	67913	94376	69279	93955	28
33	66513	94773	67936	94369	69301	93948	27
34	66537	94767	67959	94362	69323	93941	26
35	66562	94760	67982	94355	69345	93934	25
36	66586	94753	68006	94349	69368	93927	24
37	66610	94747	68029	94342	69390	93920	23
38	66634	94740	68052	94335	69412	93912	22
39	66658	94734	68075	94328	69434	93905	21
40	9.66682	9.94727	9.68098	9.94321	9.69456	9.93898	20
41	66706	94720	68121	94314	69479	93891	19
42	66731	94714	68144	94307	69501	93884	18
43	66755	94707	68167	94300	69523	93876	17
44	66779	94700	68190	94293	69545	93869	16
45	66803	94694	68213	94286	69567	93862	15
46	66827	94687	68237	94279	69589	93855	14
47	66851	94680	68260	94273	69611	93847	13
48	66875	94674	68283	94266	69633	93840	12
49	66899	94667	68305	94259	69655	93833	11
50	9.66922	9.94660	9.68328	9.94252	9.69677	9.93826	10
51	66946	94654	68351	94245	69699	93819	9
52	66970	94647	68374	94238	69721	93811	8
53	66994	94640	68397	94231	69743	93804	7
54	67018	94634	68420	94224	69765	93797	6
55	67042	94627	68443	94217	69787	93789	5
56	67066	94620	68466	94210	69809	93782	4
57	67090	94614	68489	94203	69831	93775	3
58	67113	94607	68512	94196	69853	93768	2
59	67137	94600	68534	94189	69875	93760	1
60	67161	94593	68557	94182	69897	93753	0
	62°		61°		60°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	30°		31°		32°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.69897	9.93753	9.71184	9.93307	9.72421	9.92842	60
1	69919	93746	71205	93299	72441	92834	59
2	69941	93738	71226	93291	72461	92826	58
3	69963	93731	71247	93284	72482	92818	57
4	69984	93724	71268	93276	72502	92810	56
5	70006	93717	71289	93269	72522	92803	55
6	70028	93709	71310	93261	72542	92795	54
7	70050	93702	71331	93253	72562	92787	53
8	70072	93695	71352	93246	72582	92779	52
9	70093	93687	71373	93238	72602	92771	51
10	9.70115	9.93680	9.71393	9.93230	9.72622	9.92763	50
11	70137	93673	71414	93222	72642	92755	49
12	70159	93665	71435	93215	72663	92747	48
13	70180	93658	71456	93207	72683	92739	47
14	70202	93650	71477	93200	72703	92731	46
15	70224	93643	71498	93192	72723	92723	45
16	70245	93636	71519	93184	72743	92715	44
17	70267	93628	71539	93177	72763	92707	43
18	70288	93621	71560	93169	72783	92699	42
19	70310	93614	71581	93161	72803	92691	41
20	9.70332	9.93606	9.71602	9.93154	9.72822	9.92683	40
21	70353	93599	71622	93146	72843	92675	39
22	70375	93591	71643	93138	72863	92667	38
23	70396	93584	71664	93131	72883	92659	37
24	70418	93577	71685	93123	72902	92651	36
25	70439	93569	71705	93115	72922	92643	35
26	70461	93562	71726	93108	72942	92635	34
27	70482	93554	71747	93100	72962	92627	33
28	70504	93547	71767	93092	72982	92619	32
29	70525	93539	71788	93084	73002	92611	31
30	9.70547	9.93532	9.71809	9.93077	9.73022	9.92603	30
31	70568	93525	71829	93069	73041	92595	29
32	70590	93517	71850	93061	73061	92587	28
33	70611	93510	71870	93053	73081	92579	27
34	70633	93502	71891	93046	73101	92571	26
35	70654	93495	71911	93038	73121	92563	25
36	70675	93487	71932	93030	73140	92555	24
37	70697	93480	71952	93022	73160	92546	23
38	70718	93472	71973	93014	73180	92538	22
39	70739	93465	71994	93007	73200	92530	21
40	9.70761	9.93457	9.72014	9.92999	9.73219	9.92522	20
41	70782	93450	72034	92991	73239	92514	19
42	70803	93442	72055	92983	73259	92506	18
43	70824	93435	72075	92976	73278	92498	17
44	70846	93427	72096	92968	73298	92490	16
45	70867	93420	72116	92960	73318	92482	15
46	70888	93412	72137	92952	73337	92473	14
47	70909	93405	72157	92944	73357	92465	13
48	70931	93397	72177	92936	73377	92457	12
49	70952	93390	72198	92929	73396	92449	11
50	9.70973	9.93382	9.72218	9.92921	9.73416	9.92441	10
51	70994	93375	72238	92913	73435	92433	9
52	71015	93367	72259	92905	73455	92425	8
53	71036	93360	72279	92897	73474	92416	7
54	71058	93352	72299	92889	73494	92408	6
55	71079	93344	72320	92881	73513	92400	5
56	71100	93337	72340	92874	73533	92392	4
57	71121	93329	72360	92866	73552	92384	3
58	71142	93322	72381	92858	73572	92376	2
59	71163	93314	72401	92850	73591	92367	1
60	71184	93307	72421	92842	73611	92359	0
	59°		58°		57°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	33°		34°		35°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.73611	9.92359	9.74756	9.91857	9.75859	9.91336	60
1	73630	92351	74775	91849	75877	91828	59
2	73650	92343	74794	91840	75895	91819	58
3	73669	92335	74812	91832	75913	91810	57
4	73689	92326	74831	91823	75931	91801	56
5	73708	92318	74850	91815	75949	91292	55
6	73727	92310	74868	91806	75967	91283	54
7	73747	92302	74887	91798	75985	91274	53
8	73766	92293	74906	91789	76003	91266	52
9	73785	92285	74924	91781	76021	91257	51
10	9.73805	9.92277	9.74943	9.91772	9.76039	9.91248	50
11	73824	92269	74961	91763	76057	91239	49
12	73843	92260	74980	91755	76075	91230	48
13	73863	92252	74999	91746	76093	91221	47
14	73882	92244	75017	91738	76111	91212	46
15	73901	92235	75036	91729	76129	91203	45
16	73921	92227	75054	91720	76146	91194	44
17	73940	92219	75073	91712	76164	91185	43
18	73959	92211	75091	91703	76182	91176	42
19	73978	92202	75110	91695	76200	91167	41
20	9.73997	9.92194	9.75128	9.91686	9.76218	9.91158	40
21	74017	92186	75147	91677	76236	91149	39
22	74036	92177	75165	91669	76253	91141	38
23	74055	92169	75184	91660	76271	91132	37
24	74074	92161	75202	91651	76289	91123	36
25	74093	92152	75221	91643	76307	91114	35
26	74113	92144	75239	91634	76324	91105	34
27	74132	92136	75258	91625	76342	91096	33
28	74151	92127	75276	91617	76360	91087	32
29	74170	92119	75294	91608	76378	91078	31
30	9.74189	9.92111	9.75313	9.91599	9.76395	9.91069	30
31	74208	92102	75331	91591	76413	91060	29
32	74227	92094	75350	91582	76431	91051	28
33	74246	92086	75368	91573	76448	91042	27
34	74265	92077	75386	91565	76466	91033	26
35	74284	92069	75405	91556	76484	91023	25
36	74303	92060	75423	91547	76501	91014	24
37	74322	92052	75441	91538	76519	91005	23
38	74341	92044	75459	91530	76537	90996	22
39	74360	92035	75478	91521	76554	90987	21
40	9.74379	9.92027	9.75496	9.91512	9.76572	9.90978	20
41	74398	92018	75514	91504	76590	90969	19
42	74417	92010	75533	91495	76607	90960	18
43	74436	92002	75551	91486	76625	90951	17
44	74455	91993	75569	91477	76642	90942	16
45	74474	91985	75587	91469	76660	90933	15
46	74493	91976	75605	91460	76677	90924	14
47	74512	91968	75624	91451	76695	90915	13
48	74531	91959	75642	91442	76712	90906	12
49	74549	91951	75660	91433	76730	90896	11
50	9.74568	9.91942	9.75678	9.91425	9.76747	9.90887	10
51	74587	91934	75696	91416	76765	90878	9
52	74606	91925	75714	91407	76782	90869	8
53	74625	91917	75733	91398	76800	90860	7
54	74644	91908	75751	91389	76817	90851	6
55	74663	91900	75769	91381	76835	90842	5
56	74681	91891	75787	91372	76852	90832	4
57	74700	91883	75805	91363	76870	90823	3
58	74719	91874	75823	91354	76887	90814	2
59	74737	91866	75841	91345	76904	90805	1
60	74756	91857	75859	91336	76922	90796	0
	56°		55°		54°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	86°		87°		88°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.76922	9.90796	9.77946	9.90235	9.78984	9.89658	60
1	76939	90787	77963	90225	78950	89643	59
2	76957	90777	77980	90216	78967	89633	58
3	76974	90768	77997	90206	78983	89624	57
4	76991	90759	78013	90197	78999	89614	56
5	77009	90750	78030	90187	79015	89604	55
6	77026	90741	78047	90178	79031	89594	54
7	77043	90731	78063	90168	79047	89584	53
8	77061	90722	78080	90159	79063	89574	52
9	77078	90713	78097	90149	79079	89564	51
10	9.77095	9.90704	9.78113	9.90139	9.79095	9.89554	50
11	77112	90694	78130	90130	79111	89544	49
12	77130	90685	78147	90120	79128	89534	48
13	77147	90676	78163	90111	79144	89524	47
14	77164	90667	78180	90101	79160	89514	46
15	77181	90657	78197	90091	79176	89504	45
16	77199	90648	78213	90082	79192	89495	44
17	77216	90639	78230	90072	79208	89485	43
18	77233	90630	78246	90063	79224	89475	42
19	77250	90620	78263	90053	79240	89465	41
20	9.77268	9.90611	9.78280	9.90043	9.79256	9.89455	40
21	77285	90602	78296	90034	79272	89445	39
22	77302	90592	78313	90024	79288	89435	38
23	77319	90583	78329	90014	79304	89425	37
24	77336	90574	78346	90005	79319	89415	36
25	77353	90565	78362	89995	79335	89405	35
26	77370	90555	78379	89985	79351	89395	34
27	77387	90546	78395	89976	79367	89385	33
28	77405	90537	78412	89966	79383	89375	32
29	77422	90527	78428	89956	79399	89364	31
30	9.77439	9.90518	9.78445	9.89947	9.79415	9.89354	30
31	77455	90509	78461	89937	79431	89344	29
32	77473	90499	78478	89927	79447	89334	28
33	77490	90490	78494	89918	79463	89324	27
34	77507	90480	78510	89908	79478	89314	26
35	77524	90471	78527	89898	79494	89304	25
36	77541	90462	78543	89888	79510	89294	24
37	77558	90452	78560	89879	79526	89284	23
38	77575	90443	78576	89869	79542	89274	22
39	77592	90434	78592	89859	79558	89264	21
40	9.77609	9.90424	9.78609	9.89849	9.79573	9.89254	20
41	77626	90415	78625	89840	79589	89244	19
42	77643	90405	78642	89830	79605	89233	18
43	77660	90396	78658	89820	79621	89223	17
44	77677	90386	78674	89810	79636	89213	16
45	77694	90377	78691	89801	79652	89203	15
46	77711	90368	78707	89791	79668	89193	14
47	77728	90358	78723	89781	79684	89183	13
48	77744	90349	78739	89771	79699	89173	12
49	77761	90339	78756	89761	79715	89162	11
50	9.77778	9.90330	9.78772	9.89752	9.79731	9.89152	10
51	77795	90320	78788	89742	79746	89142	9
52	77812	90311	78805	89732	79762	89132	8
53	77829	90301	78821	89722	79778	89122	7
54	77846	90292	78837	89712	79793	89112	6
55	77862	90282	78853	89702	79809	89101	5
56	77879	90273	78869	89693	79825	89091	4
57	77896	90263	78886	89683	79840	89081	3
58	77913	90254	78902	89673	79856	89071	2
59	77930	90244	78918	89663	79872	89060	1
60	77946	90235	78934	89653	79887	89050	0
	53°		52°		51°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	39°		40°		41°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.79887	9.89050	9.80807	9.88425	9.81694	9.87778	60
1	79903	89040	80822	88415	81709	87767	59
2	79918	89030	80837	88404	81723	87756	58
3	79934	89020	80852	88394	81738	87745	57
4	79950	89009	80867	88383	81752	87734	56
5	79965	88999	80882	88373	81767	87723	55
6	79981	88989	80897	88363	81781	87712	54
7	79996	88978	80912	88351	81796	87701	53
8	80012	88968	80927	88340	81810	87690	52
9	80027	88958	80942	88330	81825	87679	51
10	9.80043	9.88948	9.80957	9.88319	9.81839	9.87668	50
11	80058	88937	80972	88308	81854	87657	49
12	80074	88927	80987	88298	81868	87646	48
13	80089	88917	81002	88287	81882	87635	47
14	80105	88906	81017	88276	81897	87624	46
15	80120	88896	81032	88266	81911	87613	45
16	80136	88886	81047	88255	81926	87601	44
17	80151	88875	81061	88244	81940	87590	43
18	80166	88865	81076	88234	81955	87579	42
19	80182	88855	81091	88223	81969	87568	41
20	9.80197	9.88844	9.81106	9.88212	9.81988	9.87557	40
21	80213	88834	81121	88201	81998	87546	39
22	80228	88824	81136	88191	82012	87535	38
23	80244	88813	81151	88180	82026	87524	37
24	80259	88803	81166	88169	82041	87513	36
25	80274	88793	81180	88158	82055	87501	35
26	80290	88782	81195	88148	82069	87490	34
27	80305	88772	81210	88137	82084	87479	33
28	80320	88761	81225	88126	82098	87468	32
29	80336	88751	81240	88115	82112	87457	31
30	9.80351	9.88741	9.81254	9.88105	9.82126	9.87446	30
31	80366	88730	81269	88094	82141	87434	29
32	80382	88720	81284	88083	82155	87423	28
33	80397	88709	81299	88072	82169	87412	27
34	80412	88699	81314	88061	82184	87401	26
35	80428	88688	81328	88051	82198	87390	25
36	80443	88678	81343	88040	82212	87378	24
37	80458	88668	81358	88029	82226	87367	23
38	80473	88657	81372	88018	82240	87356	22
39	80489	88647	81387	88007	82255	87345	21
40	9.80504	9.88636	9.81402	9.87996	9.82269	9.87334	20
41	80519	88626	81417	87985	82283	87322	19
42	80534	88615	81431	87975	82297	87311	18
43	80550	88605	81446	87964	82311	87300	17
44	80565	88594	81461	87953	82326	87288	16
45	80580	88584	81475	87943	82340	87277	15
46	80595	88573	81490	87931	82354	87266	14
47	80610	88563	81505	87920	82368	87255	13
48	80625	88552	81519	87909	82383	87243	12
49	80641	88542	81534	87898	82396	87232	11
50	9.80656	9.88531	9.81549	9.87887	9.82410	9.87221	10
51	80671	88521	81563	87877	82424	87209	9
52	80686	88510	81578	87866	82439	87198	8
53	80701	88499	81592	87855	82453	87187	7
54	80716	88489	81607	87844	82467	87175	6
55	80731	88478	81622	87833	82481	87164	5
56	80746	88468	81636	87823	82495	87153	4
57	80762	88457	81651	87811	82509	87141	3
58	80777	88447	81665	87800	82523	87130	2
59	80792	88436	81680	87789	82537	87119	1
60	80807	88425	81694	87778	82551	87107	0
	50°		49°		48°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XX.—LOGARITHMIC SINES AND COSINES.

	42°		43°		44°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	9.82551	9.87107	9.83378	9.86418	9.84177	9.85693	60
1	82565	87096	83392	86401	84190	85681	59
2	82579	87085	83405	86389	84208	85669	58
3	82593	87073	83419	86377	84216	85657	57
4	82607	87062	83432	86366	84229	85645	56
5	82621	87050	83446	86354	84242	85632	55
6	82635	87039	83459	86342	84255	85620	54
7	82649	87028	83473	86330	84269	85608	53
8	82663	87016	83486	86318	84282	85596	52
9	82677	87005	83500	86306	84295	85583	51
10	9.82691	9.86993	9.83513	9.86295	9.84308	9.85571	50
11	82705	86982	83527	86283	84321	85559	49
12	82719	86970	83540	86271	84334	85547	48
13	82733	86959	83554	86259	84347	85534	47
14	82747	86947	83567	86247	84360	85522	46
15	82761	86936	83581	86235	84373	85510	45
16	82775	86924	83594	86223	84385	85497	44
17	82788	86913	83608	86211	84398	85485	43
18	82802	86902	83621	86200	84411	85473	42
19	82816	86890	83634	86188	84424	85460	41
20	9.82830	9.86879	9.83648	9.86176	9.84437	9.85448	40
21	82844	86867	83661	86164	84450	85436	39
22	82858	86855	83674	86152	84463	85423	38
23	82872	86844	83688	86140	84476	85411	37
24	82885	86832	83701	86128	84489	85399	36
25	82899	86821	83715	86116	84502	85386	35
26	82913	86809	83728	86104	84515	85374	34
27	82927	86798	83741	86092	84528	85361	33
28	82941	86786	83755	86080	84540	85349	32
29	82955	86775	83768	86068	84553	85337	31
30	9.82968	9.86763	9.83781	9.86056	9.84566	9.85324	30
31	82982	86752	83795	86044	84579	85312	29
32	82996	86740	83808	86032	84592	85299	28
33	83010	86728	83821	86020	84605	85287	27
34	83023	86717	83834	86008	84618	85274	26
35	83037	86705	83848	85996	84630	85262	25
36	83051	86694	83861	85984	84643	85250	24
37	83065	86682	83874	85972	84656	85237	23
38	83078	86670	83887	85960	84669	85225	22
39	83092	86659	83901	85948	84682	85212	21
40	9.83106	9.86647	9.83914	9.85936	9.84694	9.85200	20
41	83120	86635	83927	85924	84707	85187	19
42	83133	86624	83940	85912	84720	85175	18
43	83147	86612	83954	85900	84733	85162	17
44	83161	86600	83967	85888	84745	85150	16
45	83174	86589	83980	85876	84758	85137	15
46	83188	86577	83993	85864	84771	85125	14
47	83202	86565	84006	85851	84784	85112	13
48	83215	86554	84020	85839	84796	85100	12
49	83229	86542	84033	85827	84809	85087	11
50	9.83242	9.86530	9.84046	9.85815	9.84822	9.85074	10
51	83256	86518	84059	85803	84835	85062	9
52	83270	86507	84072	85791	84847	85049	8
53	83283	86495	84085	85779	84860	85037	7
54	83297	86483	84098	85766	84873	85024	6
55	83310	86472	84112	85754	84885	85012	5
56	83324	86460	84125	85742	84898	84999	4
57	83338	86448	84138	85730	84911	84986	3
58	83351	86436	84151	85718	84923	84974	2
59	83365	86425	84164	85706	84936	84961	1
60	83378	86413	84177	85693	84949	84949	0
	47°		46°		45°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	0°		1°		2°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	— ∞	∞	8.24192	11.75808	8.54308	11.45692	60
1	6.46878	18.53827	24910	75090	54669	45331	59
2	76476	23524	25616	74384	55027	44973	58
3	94085	05915	26312	73688	55382	44618	57
4	7.06579	12.93421	26996	73004	55734	44266	56
5	16270	83730	27669	72331	56083	43917	55
6	24188	75812	28332	71668	56429	43571	54
7	30882	69118	28986	71014	56773	43227	53
8	36682	63818	29629	70371	57114	42886	52
9	41797	58208	30263	69737	57452	42548	51
10	7.46878	12.53827	8.30688	11.69112	8.57788	11.42212	50
11	50512	49488	31505	68495	58121	41879	49
12	54291	45709	32112	67888	58451	41549	48
13	57767	42233	32711	67289	58779	41221	47
14	60986	39014	33302	66696	59105	40895	46
15	63982	36018	33886	66114	59428	40572	45
16	66785	33215	34461	65539	59749	40251	44
17	69418	30582	35029	64971	60068	39932	43
18	71900	28100	35590	64410	60384	39616	42
19	74248	25752	36143	63857	60698	39302	41
20	7.76476	12.23524	8.36689	11.63311	8.61009	11.38991	40
21	78595	21405	37229	62771	61319	38681	39
22	80615	19385	37762	62238	61626	38374	38
23	82546	17454	38289	61711	61931	38069	37
24	84394	15606	38809	61191	62234	37766	36
25	86167	13833	39323	60677	62535	37465	35
26	87871	12129	39832	60168	62834	37166	34
27	89510	10490	40334	59666	63131	36869	33
28	91089	08911	40830	59170	63426	36574	32
29	92618	07387	41321	58679	63718	36282	31
30	7.94086	12.06914	8.41807	11.58193	8.64009	11.35991	30
31	95510	04490	42287	57718	64298	35702	29
32	96889	03111	42762	57238	64585	35415	28
33	98225	01775	43232	56768	64870	35130	27
34	99522	00478	43696	56304	65154	34846	26
35	8.00781	11.99219	44156	55844	65435	34565	25
36	03004	97996	44611	55389	65715	34285	24
37	03194	96806	45061	54939	65993	34007	23
38	04853	95647	45507	54488	66269	33731	22
39	05481	94519	45948	54032	66543	33457	21
40	8.06581	11.93419	8.46885	11.53615	8.66816	11.33164	20
41	07653	92347	46317	53183	67087	32913	19
42	08700	91300	46745	52755	67356	32644	18
43	09722	90278	47169	52331	67624	32376	17
44	10720	89280	47589	51911	67890	32110	16
45	11696	88304	48005	51495	68154	31846	15
46	12651	87349	48417	51083	68417	31583	14
47	13585	86415	48825	50675	68678	31322	13
48	14500	85500	49229	50271	68938	31062	12
49	15395	84605	50130	49870	69196	30804	11
50	8.16273	11.83727	8.50527	11.49473	8.69453	11.30547	10
51	17133	83987	50920	49060	69708	30522	9
52	17976	83024	51310	48690	69962	30388	8
53	18804	81196	51696	48304	70214	29786	7
54	19616	80384	52079	47921	70465	29535	6
55	20413	79587	52459	47541	70714	29286	5
56	21195	78806	52835	47165	70962	29038	4
57	21964	78036	53208	46792	71208	28792	3
58	22720	77280	53578	46422	71453	28547	2
59	23462	76538	53945	46055	71697	28303	1
60	24192	75808	54308	45692	71940	28060	0
	89°		88°		87°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	3°		4°		5°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	8.71940	11.28060	8.84464	11.15536	8.94195	11.05805	60
1	72181	27819	84646	15354	94340	05660	59
2	72420	27580	84826	15174	94485	05515	58
3	72659	27341	85006	14994	94630	05370	57
4	72896	27104	85185	14815	94773	05227	56
5	73132	26868	85363	14637	94917	05083	55
6	73366	26634	85540	14460	95060	04940	54
7	73600	26400	85717	14283	95202	04798	53
8	73832	26163	85893	14107	95344	04656	52
9	74063	25937	86069	13931	95486	04514	51
10	8.74292	11.25708	8.86243	11.13757	8.95627	11.04373	50
11	74521	25479	86417	13583	95767	04233	49
12	74748	25252	86591	13409	95908	04092	48
13	74974	25026	86763	13237	96047	03953	47
14	75199	24801	86935	13065	96187	03813	46
15	75423	24577	87106	12894	96325	03675	45
16	75645	24355	87277	12723	96464	03536	44
17	75867	24133	87447	12553	96602	03398	43
18	76087	23913	87616	12384	96739	03261	42
19	76306	23694	87785	12215	96877	03123	41
20	8.76525	11.23475	8.87953	11.12047	8.97013	11.02987	40
21	76742	23258	88120	11880	97150	02850	39
22	76958	23042	88287	11713	97285	02715	38
23	77173	22827	88453	11547	97421	02579	37
24	77387	22613	88618	11382	97556	02444	36
25	77600	22400	88783	11217	97691	02309	35
26	77811	22189	88948	11052	97825	02175	34
27	78022	21978	89111	10889	97959	02041	33
28	78232	21768	89274	10726	98093	01908	32
29	78441	21559	89437	10563	98225	01775	31
30	8.78649	11.21351	8.89598	11.10402	8.98358	11.01642	30
31	78855	21145	89760	10240	98490	01510	29
32	79061	20939	89920	10080	98622	01378	28
33	79266	20734	90080	99220	98753	01247	27
34	79470	20530	90240	9760	98884	01116	26
35	79673	20327	90399	9601	99015	00985	25
36	79875	20125	90557	9443	99145	00855	24
37	80076	19924	90715	9285	99275	00725	23
38	80277	19723	90872	9128	99405	00595	22
39	80476	19524	91029	8971	99534	00466	21
40	8.80674	11.19326	8.91185	11.08815	8.99662	11.00338	20
41	80872	19128	91340	8860	99791	00209	19
42	81068	18932	91495	86506	99919	00081	18
43	81264	18736	91650	8450	9.00046	10.99954	17
44	81459	18541	91803	82197	00174	99826	16
45	81653	18347	91957	80043	00301	99699	15
46	81846	18154	92110	77890	00427	99573	14
47	82038	17962	92262	75738	00553	99447	13
48	82230	17770	92414	73586	00679	99321	12
49	82420	17580	92565	71435	00805	99195	11
50	8.82610	11.17390	8.92716	11.07284	9.00930	10.99070	10
51	82799	17201	92866	69184	01055	98945	9
52	82987	17013	93016	66984	01179	98821	8
53	83175	16825	93165	64835	01303	98697	7
54	83361	16639	93313	62687	01427	98573	6
55	83547	16453	93462	60538	01550	98450	5
56	83732	16268	93609	58391	01673	98327	4
57	83916	16084	93756	56244	01796	98204	3
58	84100	15900	93903	54097	01918	98082	2
59	84282	15718	94049	51951	02040	97960	1
60	84464	15536	94195	49805	02162	97838	0
	86°		85°		84°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	6°		7°		8°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.02162	10.97838	9.08914	10.91086	9.14780	10.85220	60
1	02288	97717	09019	90981	14872	85128	59
2	02404	97596	09123	90877	14963	85037	58
3	02525	97475	09227	90773	15054	84946	57
4	02645	97355	09330	90670	15145	84855	56
5	02766	97234	09434	90566	15236	84764	55
6	02885	97115	09537	90463	15327	84673	54
7	03005	96995	09640	90360	15417	84583	53
8	03124	96876	09742	90258	15508	84492	52
9	03242	96758	09845	90155	15598	84402	51
10	9.03361	10.96639	9.09947	10.90053	9.15688	10.84312	50
11	03479	96521	10049	89951	15777	84223	49
12	03597	96403	10150	89850	15867	84133	48
13	03714	96286	10252	89748	15956	84044	47
14	03832	96168	10353	89647	16046	83954	46
15	03948	96052	10454	89546	16135	83865	45
16	04065	95935	10555	89445	16224	83776	44
17	04181	95819	10656	89344	16312	83688	43
18	04297	95703	10756	89244	16401	83599	42
19	04413	95587	10856	89144	16489	83511	41
20	9.04528	10.95472	9.10956	10.89044	9.16577	10.83423	40
21	04643	95357	11056	88944	16665	83335	39
22	04758	95242	11155	88845	16753	83247	38
23	04873	95127	11254	88746	16841	83159	37
24	04987	95013	11353	88647	16928	83072	36
25	05101	94899	11452	88548	17016	82984	35
26	05214	94786	11551	88449	17103	82897	34
27	05328	94672	11649	88351	17190	82810	33
28	05441	94559	11747	88253	17277	82723	32
29	05553	94447	11845	88155	17363	82637	31
30	9.05666	10.94334	9.11943	10.88057	9.17450	10.82550	30
31	05778	94222	12040	87960	17536	82464	29
32	05890	94110	12138	87862	17622	82378	28
33	06002	93998	12235	87765	17708	82292	27
34	06118	93887	12332	87668	17794	82206	26
35	06224	93776	12428	87572	17880	82120	25
36	06335	93665	12525	87475	17965	82035	24
37	06445	93555	12621	87379	18051	81949	23
38	06556	93444	12717	87283	18136	81864	22
39	06666	93334	12813	87187	18221	81779	21
40	9.06775	10.93225	9.12909	10.87091	9.18306	10.81694	20
41	06885	93115	13004	86996	18391	81609	19
42	06994	93006	13099	86901	18475	81525	18
43	07103	92897	13194	86806	18560	81440	17
44	07211	92789	13289	86711	18644	81356	16
45	07320	92680	13384	86616	18728	81272	15
46	07428	92572	13478	86522	18812	81188	14
47	07536	92464	13573	86427	18896	81104	13
48	07643	92357	13667	86333	18979	81021	12
49	07751	92249	13761	86239	19063	80937	11
50	9.07858	10.92142	9.13854	10.86146	9.19146	10.80854	10
51	07964	92036	13848	86052	19229	80771	9
52	08071	91929	14041	85959	19312	80688	8
53	08177	91823	14134	85866	19395	80605	7
54	08288	91717	14227	85773	19478	80522	6
55	08389	91611	14320	85680	19561	80439	5
56	08495	91505	14412	85588	19643	80357	4
57	08600	91400	14504	85496	19725	80275	3
58	08705	91295	14597	85403	19807	80193	2
59	08810	91190	14688	85312	19889	80111	1
60	08914	91086	14780	85220	19971	80029	0
	88°		89°		90°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

9°		10°		11°		
Tan	Cotan	Tan	Cotan	Tan	Cotan	
9.18971	10.80029	9.24632	10.75368	9.29865	10.71135	60
20053	79947	24706	75294	29883	71067	59
20134	79866	24779	75221	29900	71000	58
20216	79784	24853	75147	29967	70933	57
20297	79703	24926	75074	29984	70866	56
20378	79622	25000	75000	29991	70799	55
20459	79541	25073	74927	29998	70732	54
20540	79460	25146	74854	29999	70665	53
20621	79379	25219	74781	29999	70598	52
20701	79299	25292	74708	29999	70532	51
9.20783	10.79218	9.25365	10.74635	9.29535	10.70465	50
20863	79138	25437	74563	29961	70399	49
20942	79058	25510	74490	29968	70332	48
21022	78978	25582	74418	29974	70266	47
21102	78898	25655	74345	29980	70200	46
21182	78818	25727	74273	29986	70134	45
21261	78739	25799	74201	29989	70068	44
21341	78659	25871	74129	29996	70002	43
21420	78580	25943	74057	30004	69936	42
21499	78501	26015	73985	30180	69870	41
9.21578	10.78422	9.26066	10.73914	9.30195	10.69805	40
21657	78343	26158	73842	30261	69739	39
21736	78264	26229	73771	30326	69674	38
21814	78186	26301	73699	30391	69609	37
21893	78107	26372	73628	30457	69543	36
21971	78029	26443	73557	30522	69478	35
22049	77951	26514	73486	30587	69413	34
22127	77873	26585	73415	30652	69348	33
22205	77795	26655	73345	30717	69283	32
22283	77717	26726	73274	30782	69218	31
9.22361	10.77639	9.26797	10.73203	9.30646	10.69154	30
22438	77632	26867	73133	30911	69089	29
22516	77484	26937	73063	30975	69025	28
22593	77407	27008	72992	31040	68960	27
22670	77330	27078	72922	31104	68896	26
22747	77253	27148	72852	31168	68832	25
22824	77176	27218	72783	31233	68767	24
22901	77099	27288	72712	31297	68703	23
22977	77023	27357	72643	31361	68639	22
23054	76946	27427	72573	31425	68575	21
9.23130	10.76870	9.27496	10.72504	9.31489	10.68511	20
23206	76794	27566	72434	31553	68448	19
23283	76717	27635	72365	31616	68384	18
23359	76641	27704	72296	31679	68321	17
23435	76565	27773	72227	31743	68257	16
23510	76490	27842	72158	31806	68194	15
23586	76414	27911	72089	31870	68130	14
23661	76339	27980	72020	31933	68067	13
23737	76263	28049	71951	31996	68004	12
23812	76188	28117	71883	32059	67941	11
9.23887	10.76113	9.28186	10.71814	9.32122	10.67878	10
23962	76038	28254	71746	32185	67815	9
24037	75963	28323	71677	32248	67752	8
24112	75888	28391	71609	32311	67689	7
24186	75814	28459	71541	32373	67627	6
24261	75739	28527	71473	32436	67564	5
24335	75665	28595	71405	32498	67502	4
24410	75590	28662	71338	32561	67439	3
24484	75516	28730	71270	32623	67377	2
24558	75442	28798	71202	32685	67315	1
24632	75368	28865	71135	32747	67253	0
Cotan	Tan	Cotan	Tan	Cotan	Tan	
80°		79°		78°		

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	12°		13°		14°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.82747	10.67253	9.86396	10.63604	9.89677	10.60323	60
1	82810	67190	86394	63606	89781	60269	59
2	82872	67128	86452	63548	89785	60215	58
3	82933	67067	86509	63491	89838	60162	57
4	82995	67005	86566	63434	89892	60108	56
5	83057	66943	86624	63376	89945	60055	55
6	83119	66881	86681	63319	89999	60001	54
7	83180	66820	86738	63262	40052	59948	53
8	83242	66758	86795	63205	40106	59894	52
9	83303	66697	86852	63148	40159	59841	51
10	9.83365	10.66635	9.86909	10.63091	9.40212	10.59788	50
11	83426	66574	86966	63034	40266	59734	49
12	83487	66511	87023	62977	40319	59681	48
13	83548	66452	87080	62920	40372	59628	47
14	83609	66391	87137	62863	40425	59575	46
15	83670	66330	87193	62807	40478	59522	45
16	83731	66269	87250	62750	40531	59469	44
17	83792	66208	87306	62694	40584	59416	43
18	83853	66147	87363	62637	40636	59364	42
19	83913	66087	87419	62581	40689	59311	41
20	9.83974	10.66026	9.87476	10.62524	9.40742	10.59258	40
21	84034	65966	87532	62468	40795	59205	39
22	84095	65905	87588	62412	40847	59153	38
23	84155	65845	87644	62356	40900	59100	37
24	84215	65785	87700	62300	40952	59048	36
25	84276	65724	87756	62244	41005	58995	35
26	84336	65664	87812	62188	41057	58943	34
27	84396	65604	87868	62132	41109	58891	33
28	84456	65544	87924	62076	41161	58839	32
29	84516	65484	87980	62020	41214	58786	31
30	9.84576	10.65424	9.88035	10.61965	9.41266	10.58784	30
31	84635	65365	88091	61909	41318	58682	29
32	84695	65305	88147	61853	41370	58630	28
33	84755	65245	88202	61798	41422	58578	27
34	84814	65186	88257	61743	41474	58526	26
35	84874	65126	88313	61687	41526	58474	25
36	84933	65067	88368	61632	41578	58422	24
37	84992	65008	88423	61577	41629	58371	23
38	85051	64949	88479	61521	41681	58319	22
39	85111	64889	88534	61466	41733	58267	21
40	9.85170	10.64880	9.88589	10.61411	9.41784	10.58216	20
41	85229	64771	88644	61356	41836	58164	19
42	85288	64712	88699	61301	41887	58118	18
43	85347	64653	88754	61246	41939	58061	17
44	85405	64595	88808	61192	41990	58010	16
45	85464	64536	88863	61137	42041	57959	15
46	85523	64477	88918	61082	42093	57907	14
47	85581	64419	88972	61028	42144	57856	13
48	85640	64360	89027	60973	42195	57805	12
49	85698	64302	89082	60918	42246	57754	11
50	9.85757	10.64243	9.89136	10.60864	9.42297	10.57708	10
51	85815	64185	89190	60810	42348	57652	9
52	85873	64127	89245	60755	42399	57601	8
53	85931	64069	89299	60701	42450	57550	7
54	85989	64011	89353	60647	42501	57499	6
55	86047	63953	89407	60593	42552	57448	5
56	86105	63895	89461	60539	42603	57397	4
57	86163	63837	89515	60485	42653	57347	3
58	86221	63779	89569	60431	42704	57296	2
59	86279	63721	89623	60377	42755	57245	1
60	86336	63664	89677	60323	42805	57195	0
	77°		76°		75°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	15°		16°		17°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.42805	10.57195	9.45750	10.54250	9.48584	10.51416	60
1	42856	57144	45797	54203	48579	51421	59
2	42906	57094	45845	54155	48624	51376	58
3	42957	57043	45892	54108	48669	51331	57
4	43007	56993	45940	54060	48714	51286	56
5	43057	56943	45987	54013	48759	51241	55
6	43108	56892	46035	53965	48804	51196	54
7	43158	56842	46082	53918	48849	51151	53
8	43208	56792	46130	53870	48894	51106	52
9	43258	56742	46177	53823	48939	51061	51
10	9.43308	10.56692	9.46224	10.53776	9.48984	10.51016	50
11	43358	56642	46271	53729	49029	50971	49
12	43408	56592	46319	53681	49073	50927	48
13	43458	56542	46366	53634	49118	50882	47
14	43508	56492	46413	53587	49163	50837	46
15	43558	56442	46460	53540	49207	50793	45
16	43607	56393	46507	53493	49252	50748	44
17	43657	56343	46554	53446	49296	50704	43
18	43707	56293	46601	53399	49341	50659	42
19	43756	56244	46648	53352	49385	50615	41
20	9.43806	10.56194	9.46694	10.53306	9.49430	10.50870	40
21	43856	56145	46741	53259	49474	50626	39
22	43905	56095	46788	53212	49519	50481	38
23	43954	56046	46835	53165	49563	50437	37
24	44004	55996	46881	53119	49607	50393	36
25	44053	55947	46928	53072	49652	50348	35
26	44102	55898	46975	53025	49696	50304	34
27	44151	55849	47021	52979	49740	50260	33
28	44201	55799	47068	52932	49784	50216	32
29	44250	55750	47114	52886	49828	50172	31
30	9.44399	10.55701	9.47160	10.52840	9.49872	10.50128	30
31	44348	55652	47207	52793	49916	50084	29
32	44397	55603	47253	52747	49960	50040	28
33	44446	55554	47299	52701	50004	49996	27
34	44495	55505	47346	52654	50048	49952	26
35	44544	55456	47392	52608	50092	49908	25
36	44593	55408	47438	52562	50136	49864	24
37	44641	55359	47484	52516	50180	49820	23
38	44690	55310	47530	52470	50223	49777	22
39	44738	55262	47576	52424	50267	49733	21
40	9.44787	10.55213	9.47622	10.52378	9.50811	10.49689	20
41	44836	55164	47668	52332	50855	49645	19
42	44884	55116	47714	52286	50898	49602	18
43	44933	55067	47760	52240	50942	49558	17
44	44981	55019	47806	52194	50985	49515	16
45	45029	54971	47852	52148	51029	49471	15
46	45078	54922	47897	52103	51072	49428	14
47	45126	54874	47943	52057	51116	49384	13
48	45174	54826	47989	52011	51159	49341	12
49	45222	54778	48035	51965	51203	49297	11
50	9.45271	10.54729	9.48080	10.51920	9.50746	10.49254	10
51	45319	54681	48126	51874	50789	49211	9
52	45367	54633	48171	51829	50833	49167	8
53	45415	54585	48217	51783	50876	49124	7
54	45463	54537	48262	51738	50919	49081	6
55	45511	54489	48307	51693	50962	49038	5
56	45559	54441	48353	51647	51005	48995	4
57	45606	54394	48398	51602	51048	48952	3
58	45654	54346	48443	51557	51092	48908	2
59	45702	54298	48489	51511	51135	48865	1
60	45750	54250	48534	51466	51178	48822	0
	Cotan	Tan	Cotan	Tan	Cotan	Tan	
	74°		73°		72°		

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	18°		19°		20°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.51178	10.48822	9.53697	10.46303	9.56107	10.43893	60
1	51221	48779	53738	46262	56146	43854	59
2	51264	48736	53779	46221	56185	43815	58
3	51306	48694	53820	46180	56224	43776	57
4	51349	48651	53861	46139	56264	43736	56
5	51392	48608	53902	46098	56303	43697	55
6	51435	48565	53943	46057	56342	43658	54
7	51478	48522	53984	46016	56381	43619	53
8	51520	48480	54025	45975	56420	43580	52
9	51563	48437	54065	45935	56459	43541	51
10	9.51606	10.48394	9.54106	10.45894	9.56498	10.43502	50
11	51648	48352	54147	45853	56537	43463	49
12	51691	48309	54187	45813	56576	43424	48
13	51734	48266	54228	45772	56615	43385	47
14	51776	48224	54269	45731	56654	43346	46
15	51819	48181	54309	45691	56693	43307	45
16	51861	48139	54350	45650	56732	43268	44
17	51903	48097	54390	45610	56771	43229	43
18	51946	48054	54431	45569	56810	43190	42
19	51988	48012	54471	45529	56849	43151	41
20	9.52031	10.47969	9.54512	10.45488	9.56887	10.43118	40
21	52073	47927	54552	45448	56926	43074	39
22	52115	47885	54593	45407	56965	43035	38
23	52157	47843	54633	45367	57004	42996	37
24	52200	47800	54673	45327	57042	42958	36
25	52242	47758	54714	45286	57081	42919	35
26	52284	47716	54754	45246	57120	42880	34
27	52326	47674	54794	45206	57158	42842	33
28	52368	47632	54835	45165	57197	42803	32
29	52410	47590	54875	45125	57235	42765	31
30	9.52452	10.47548	9.54915	10.45085	9.57274	10.42726	30
31	52494	47506	54955	45045	57312	42688	29
32	52536	47464	54995	45005	57351	42649	28
33	52578	47422	55035	44965	57389	42611	27
34	52620	47380	55075	44925	57428	42572	26
35	52661	47339	55115	44885	57466	42534	25
36	52703	47297	55155	44845	57504	42496	24
37	52745	47255	55195	44805	57543	42457	23
38	52787	47213	55235	44765	57581	42419	22
39	52829	47171	55275	44725	57619	42381	21
40	9.52870	10.47130	9.55815	10.44685	9.57658	10.42342	20
41	52912	47088	55855	44645	57696	42304	19
42	52953	47047	55895	44605	57734	42266	18
43	52995	47005	55934	44566	57772	42228	17
44	53037	46963	55974	44526	57810	42190	16
45	53078	46922	55514	44486	57849	42151	15
46	53120	46880	55554	44446	57887	42113	14
47	53161	46839	55593	44407	57925	42075	13
48	53202	46798	55633	44367	57963	42037	12
49	53244	46756	55673	44327	58001	41999	11
50	9.53285	10.46715	9.55712	10.44288	9.58039	10.41961	10
51	53327	46673	55752	44248	58077	41923	9
52	53368	46632	55791	44209	58115	41885	8
53	53409	46591	55831	44169	58153	41847	7
54	53450	46550	55870	44130	58191	41809	6
55	53492	46508	55910	44090	58229	41771	5
56	53533	46467	55949	44051	58267	41733	4
57	53574	46426	55989	44011	58304	41696	3
58	53615	46385	56028	43972	58342	41658	2
59	53656	46344	56067	43933	58380	41620	1
60	53697	46303	56107	43893	58418	41582	0
	71°		70°		69°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	21°		22°		23°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.58418	10.41582	9.60641	10.39359	9.62785	10.37215	60
1	58455	41545	60677	39323	62820	37180	59
2	58493	41507	60714	39286	62855	37145	58
3	58531	41469	60750	39250	62890	37110	57
4	58569	41431	60786	39214	62926	37074	56
5	58606	41394	60823	39177	62961	37039	55
6	58644	41356	60859	39141	62996	37004	54
7	58681	41319	60895	39105	63031	36969	53
8	58719	41281	60931	39069	63066	36934	52
9	58757	41243	60967	39033	63101	36899	51
10	9.58794	10.41206	9.61004	10.38996	9.63135	10.36865	50
11	58832	41168	61040	38960	63170	36830	49
12	58869	41131	61076	38924	63205	36795	48
13	58907	41093	61112	38888	63240	36760	47
14	58944	41056	61148	38852	63275	36725	46
15	58981	41019	61184	38816	63310	36690	45
16	59019	40981	61220	38780	63345	36655	44
17	59056	40944	61256	38744	63379	36621	43
18	59094	40906	61292	38708	63414	36586	42
19	59131	40869	61328	38672	63449	36551	41
20	9.59168	10.40882	9.61304	10.38636	9.63484	10.36516	40
21	59205	40795	61400	38600	63519	36481	39
22	59243	40757	61436	38564	63553	36447	38
23	59280	40720	61472	38528	63588	36412	37
24	59317	40683	61508	38492	63623	36377	36
25	59354	40646	61544	38456	63657	36343	35
26	59391	40609	61579	38421	63692	36308	34
27	59429	40571	61615	38385	63726	36274	33
28	59466	40534	61651	38349	63761	36239	32
29	59503	40497	61687	38313	63796	36204	31
30	9.59540	10.40460	9.61722	10.38278	9.63830	10.36170	30
31	59577	40423	61758	38242	63865	36135	29
32	59614	40386	61794	38206	63899	36101	28
33	59651	40349	61830	38170	63934	36066	27
34	59688	40312	61865	38135	63968	36032	26
35	59725	40275	61901	38099	64003	35997	25
36	59762	40238	61936	38064	64037	35963	24
37	59799	40201	61972	38028	64072	35928	23
38	59835	40165	62008	37992	64106	35894	22
39	59872	40128	62043	37957	64140	35860	21
40	9.59909	10.40091	9.62079	10.37921	9.64175	10.35825	20
41	59946	40054	62114	37886	64209	35791	19
42	59983	40017	62150	37850	64243	35757	18
43	60019	39981	62185	37815	64278	35722	17
44	60056	39944	62221	37779	64312	35688	16
45	60093	39907	62256	37744	64346	35654	15
46	60130	39870	62292	37708	64381	35619	14
47	60166	39834	62327	37673	64415	35585	13
48	60203	39797	62362	37638	64449	35551	12
49	60240	39760	62398	37602	64483	35517	11
50	9.60276	10.39724	9.62438	10.37567	9.64517	10.35483	10
51	60313	39687	62468	37532	64552	35448	9
52	60349	39651	62504	37496	64586	35414	8
53	60386	39614	62539	37461	64620	35380	7
54	60422	39578	62574	37426	64654	35346	6
55	60459	39541	62609	37391	64688	35312	5
56	60495	39505	62645	37355	64722	35278	4
57	60532	39468	62680	37320	64756	35244	3
58	60568	39432	62715	37285	64790	35210	2
59	60605	39395	62750	37250	64824	35176	1
60	60641	39359	62785	37215	64858	35142	0
	Cotan	Tan	Cotan	Tan	Cotan	Tan	
	68°		67°		66°		

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	24°		25°		26°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.64858	10.35142	9.66867	10.33133	9.68818	10.31182	60
1	64892	35108	66900	33100	68850	31150	59
2	64926	35074	66933	33067	68882	31118	58
3	64960	35040	66966	33034	68914	31086	57
4	64994	35006	66999	33001	68946	31054	56
5	65028	34972	67032	32968	68978	31022	55
6	65062	34938	67065	32935	69010	30990	54
7	65096	34904	67098	32902	69042	30958	53
8	65130	34870	67131	32869	69074	30926	52
9	65164	34836	67163	32837	69106	30894	51
10	9.65197	10.34803	9.67196	10.32804	9.69138	10.30882	50
11	65231	34769	67229	32771	69170	30850	49
12	65265	34735	67262	32738	69202	30818	48
13	65299	34701	67295	32705	69234	30786	47
14	65333	34667	67327	32673	69266	30754	46
15	65366	34634	67360	32640	69298	30722	45
16	65400	34600	67393	32607	69329	30691	44
17	65434	34566	67426	32574	69361	30659	43
18	65467	34533	67458	32542	69393	30627	42
19	65501	34499	67491	32509	69425	30595	41
20	9.65535	10.34465	9.67524	10.32476	9.69457	10.30543	40
21	65568	34432	67556	32444	69488	30512	39
22	65602	34398	67589	32411	69520	30480	38
23	65636	34364	67622	32378	69552	30448	37
24	65669	34331	67654	32346	69584	30416	36
25	65703	34297	67687	32313	69615	30385	35
26	65736	34264	67719	32281	69647	30353	34
27	65770	34230	67752	32248	69679	30321	33
28	65803	34197	67785	32215	69710	30290	32
29	65837	34163	67817	32183	69742	30258	31
30	9.65870	10.34130	9.67850	10.32150	9.69774	10.30226	30
31	65904	34096	67882	32118	69805	30195	29
32	65937	34063	67915	32085	69837	30163	28
33	65971	34029	67947	32053	69868	30132	27
34	66004	33996	67980	32020	69900	30100	26
35	66038	33962	68012	31988	69932	30068	25
36	66071	33929	68044	31956	69963	30037	24
37	66104	33896	68077	31923	69995	30005	23
38	66138	33862	68109	31891	70026	29974	22
39	66171	33829	68142	31858	70058	29942	21
40	9.66204	10.33796	9.68174	10.31826	9.70089	10.29911	20
41	66238	33762	68206	31794	70121	29879	19
42	66271	33729	68239	31761	70152	29848	18
43	66304	33696	68271	31729	70184	29816	17
44	66337	33663	68303	31697	70215	29785	16
45	66371	33629	68336	31664	70247	29753	15
46	66404	33596	68368	31632	70278	29722	14
47	66437	33563	68400	31600	70309	29691	13
48	66470	33530	68432	31568	70341	29659	12
49	66503	33497	68465	31535	70372	29628	11
50	9.66537	10.33463	9.68497	10.31503	9.70404	10.29596	10
51	66570	33430	68529	31471	70435	29565	9
52	66603	33397	68561	31439	70466	29534	8
53	66636	33364	68593	31407	70498	29502	7
54	66669	33331	68626	31374	70529	29471	6
55	66702	33298	68658	31342	70560	29440	5
56	66735	33265	68690	31310	70592	29408	4
57	66768	33232	68722	31278	70623	29377	3
58	66801	33199	68754	31246	70654	29346	2
59	66834	33166	68786	31214	70685	29315	1
60	66867	33133	68818	31182	70717	29283	0
	65°		64°		63°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	27°		28°		29°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.70717	10.29283	9.72567	10.27433	9.74375	10.25025	60
1	70748	29252	72598	27402	74405	25595	59
2	70779	29221	72628	27372	74435	25565	58
3	70810	29190	72659	27341	74465	25535	57
4	70841	29159	72689	27311	74494	25506	56
5	70873	29127	72720	27280	74524	25476	55
6	70904	29096	72750	27250	74554	25446	54
7	70935	29065	72780	27220	74583	25417	53
8	70966	29034	72811	27189	74613	25387	52
9	70997	29003	72841	27159	74643	25357	51
10	9.71028	10.28972	9.72872	10.27128	9.74673	10.25327	50
11	71059	28941	72902	27098	74702	25298	49
12	71090	28910	72932	27068	74732	25268	48
13	71121	28879	72963	27037	74762	25238	47
14	71153	28847	72993	27007	74791	25209	46
15	71184	28816	73023	26977	74821	25179	45
16	71215	28785	73054	26946	74851	25149	44
17	71246	28754	73084	26916	74880	25120	43
18	71277	28723	73114	26886	74910	25090	42
19	71308	28692	73144	26856	74939	25061	41
20	9.71339	10.28661	9.73175	10.26835	9.74969	10.25031	40
21	71370	28660	73205	26795	74998	25002	39
22	71401	28599	73235	26765	75028	24972	38
23	71431	28569	73265	26735	75058	24942	37
24	71462	28538	73295	26705	75087	24913	36
25	71493	28507	73326	26674	75117	24883	35
26	71524	28476	73356	26644	75146	24854	34
27	71555	28445	73386	26614	75176	24824	33
28	71586	28414	73416	26584	75205	24795	32
29	71617	28383	73446	26554	75235	24765	31
30	9.71648	10.28352	9.73476	10.26534	9.75264	10.24736	30
31	71679	28321	73507	26498	75294	24706	29
32	71709	28291	73537	26468	75323	24677	28
33	71740	28260	73567	26438	75353	24647	27
34	71771	28229	73597	26408	75382	24618	26
35	71802	28198	73627	26378	75411	24589	25
36	71833	28167	73657	26348	75441	24559	24
37	71863	28137	73687	26318	75470	24530	23
38	71894	28106	73717	26288	75500	24500	22
39	71925	28075	73747	26258	75529	24471	21
40	9.71955	10.28045	9.73777	10.26223	9.75558	10.24442	20
41	71986	28014	73807	26193	75588	24412	19
42	72017	27983	73837	26163	75617	24383	18
43	72048	27952	73867	26133	75647	24353	17
44	72078	27922	73897	26103	75676	24324	16
45	72109	27891	73927	26073	75705	24295	15
46	72140	27860	73957	26043	75735	24265	14
47	72170	27830	73987	26013	75764	24236	13
48	72201	27799	74017	25983	75793	24207	12
49	72231	27769	74047	25953	75822	24178	11
50	9.72262	10.27738	9.74077	10.25923	9.75852	10.24148	10
51	72293	27707	74107	25893	75881	24119	9
52	72323	27677	74137	25863	75910	24090	8
53	72354	27646	74166	25834	75939	24061	7
54	72384	27616	74196	25804	75969	24031	6
55	72415	27585	74226	25774	75998	24002	5
56	72445	27555	74256	25744	76027	23973	4
57	72476	27524	74286	25714	76056	23944	3
58	72506	27494	74316	25684	76086	23914	2
59	72537	27463	74345	25655	76115	23885	1
60	72567	27433	74375	25625	76144	23856	0
	62°		61°		60°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	30°		31°		32°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.76144	10.23856	9.77877	10.22123	9.79579	10.20421	60
1	76178	23827	77906	22094	79607	20893	59
2	76202	23798	77935	22065	79635	20865	58
3	76231	23769	77963	22037	79663	20837	57
4	76261	23739	77992	22008	79691	20809	56
5	76290	23710	78020	21980	79719	20281	55
6	76319	23681	78049	21951	79747	20253	54
7	76348	23652	78077	21923	79776	20224	53
8	76377	23623	78106	21894	79804	20196	52
9	76406	23594	78135	21865	79832	20168	51
10	9.76435	10.23565	9.78163	10.21837	9.79860	10.20140	50
11	76404	23536	78192	21808	79888	20112	49
12	76493	23507	78220	21780	79916	20084	48
13	76522	23478	78249	21751	79944	20056	47
14	76551	23449	78277	21723	79972	20028	46
15	76580	23420	78306	21694	80000	20000	45
16	76609	23391	78334	21666	80028	19972	44
17	76639	23361	78363	21637	80056	19944	43
18	76668	23332	78391	21609	80084	19916	42
19	76697	23303	78419	21581	80112	19888	41
20	9.76725	10.23275	9.78448	10.21552	9.80140	10.19860	40
21	76754	23246	78476	21524	80168	19832	39
22	76783	23217	78505	21495	80195	19805	38
23	76812	23188	78533	21467	80223	19777	37
24	76841	23159	78562	21438	80251	19749	36
25	76870	23130	78590	21410	80279	19721	35
26	76899	23101	78618	21382	80307	19693	34
27	76928	23072	78647	21353	80335	19665	33
28	76957	23043	78675	21325	80363	19637	32
29	76986	23014	78704	21296	80391	19609	31
30	9.77015	10.22985	9.78732	10.21268	9.80419	10.19531	30
31	77044	22956	78760	21240	80447	19553	29
32	77073	22927	78789	21211	80474	19525	28
33	77101	22899	78817	21183	80502	19498	27
34	77130	22870	78845	21155	80530	19470	26
35	77159	22841	78874	21126	80558	19442	25
36	77188	22812	78902	21098	80586	19414	24
37	77217	22783	78930	21070	80614	19386	23
38	77246	22754	78959	21041	80642	19358	22
39	77274	22726	78987	21013	80669	19331	21
40	9.77303	10.22697	9.79015	10.20985	9.80697	10.19308	20
41	77332	22668	79043	20957	80725	19275	19
42	77361	22639	79072	20928	80753	19247	18
43	77390	22610	79100	20900	80781	19219	17
44	77419	22582	79128	20872	80808	19192	16
45	77447	22553	79156	20844	80836	19164	15
46	77476	22524	79185	20815	80864	19136	14
47	77505	22495	79213	20787	80892	19108	13
48	77533	22467	79241	20759	80919	19081	12
49	77562	22438	79269	20731	80947	19053	11
50	9.77591	10.22409	9.79297	10.20703	9.80975	10.19025	10
51	77619	22381	79326	20674	81003	18997	9
52	77648	22352	79354	20646	81030	18970	8
53	77677	22323	79382	20618	81058	18942	7
54	77706	22294	79410	20590	81086	18914	6
55	77734	22266	79438	20562	81113	18887	5
56	77763	22237	79466	20534	81141	18859	4
57	77791	22209	79495	20505	81169	18831	3
58	77820	22180	79523	20477	81196	18804	2
59	77849	22151	79551	20449	81224	18776	1
60	77877	22123	79579	20421	81252	18748	0
	Cotan	Tan	Cotan	Tan	Cotan	Tan	
	59°		58°		57°		

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	33°		34°		35°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.81252	10.18748	9.82599	10.17101	9.84523	10.15477	60
1	81279	18721	82926	17074	84550	15450	59
2	81307	18693	82958	17047	84576	15424	58
3	81335	18665	82980	17020	84608	15397	57
4	81362	18638	83008	16992	84630	15370	56
5	81390	18610	83035	16965	84657	15343	55
6	81418	18582	83062	16938	84684	15316	54
7	81445	18555	83089	16911	84711	15289	53
8	81473	18527	83117	16883	84738	15262	52
9	81500	18500	83144	16856	84764	15236	51
10	9.81528	10.18472	9.83171	10.16829	9.84791	10.15209	50
11	81556	18444	83198	16802	84818	15182	49
12	81583	18417	83225	16775	84845	15155	48
13	81611	18389	83252	16748	84872	15128	47
14	81638	18362	83280	16720	84899	15101	46
15	81666	18334	83307	16693	84925	15075	45
16	81693	18307	83334	16666	84952	15048	44
17	81721	18279	83361	16639	84979	15021	43
18	81748	18252	83388	16612	85006	14994	42
19	81776	18224	83415	16585	85033	14967	41
20	9.81803	10.18197	9.83442	10.16558	9.85059	10.14941	40
21	81831	18169	83470	16530	85086	14914	39
22	81858	18142	83497	16503	85113	14887	38
23	81886	18114	83524	16476	85140	14860	37
24	81913	18087	83551	16449	85166	14833	36
25	81941	18059	83578	16422	85193	14807	35
26	81968	18032	83605	16395	85220	14780	34
27	81996	18004	83632	16368	85247	14753	33
28	82023	17977	83659	16341	85273	14727	32
29	82051	17949	83686	16314	85300	14700	31
30	9.82078	10.17922	9.83713	10.16287	9.85327	10.14673	30
31	82106	17894	83740	16260	85354	14646	29
32	82133	17867	83768	16232	85380	14620	28
33	82161	17839	83795	16205	85407	14593	27
34	82188	17812	83822	16178	85434	14566	26
35	82215	17785	83849	16151	85460	14540	25
36	82243	17757	83876	16124	85487	14513	24
37	82270	17730	83903	16097	85514	14486	23
38	82298	17702	83930	16070	85540	14460	22
39	82325	17675	83957	16043	85567	14433	21
40	9.82352	10.17648	9.83984	10.16016	9.85594	10.14406	20
41	82380	17620	84011	15989	85620	14380	19
42	82407	17593	84038	15962	85647	14353	18
43	82435	17565	84065	15935	85674	14326	17
44	82462	17538	84092	15908	85700	14300	16
45	82489	17511	84119	15881	85727	14273	15
46	82517	17483	84146	15854	85754	14246	14
47	82544	17456	84173	15827	85780	14220	13
48	82571	17429	84200	15800	85807	14193	12
49	82599	17401	84227	15773	85834	14166	11
50	9.82626	10.17374	9.84254	10.15746	9.85860	10.14140	10
51	82653	17347	84280	15720	85887	14113	9
52	82681	17319	84307	15693	85913	14087	8
53	82708	17292	84334	15666	85940	14060	7
54	82735	17265	84361	15639	85967	14033	6
55	82762	17238	84388	15612	85993	14007	5
56	82790	17210	84415	15585	86020	13980	4
57	82817	17183	84442	15558	86046	13954	3
58	82844	17156	84469	15531	86073	13927	2
59	82871	17129	84496	15504	86100	13900	1
60	82899	17101	84523	15477	86126	13874	0
	Cotan	Tan	Cotan	Tan	Cotan	Tan	
	56°		55°		54°		

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

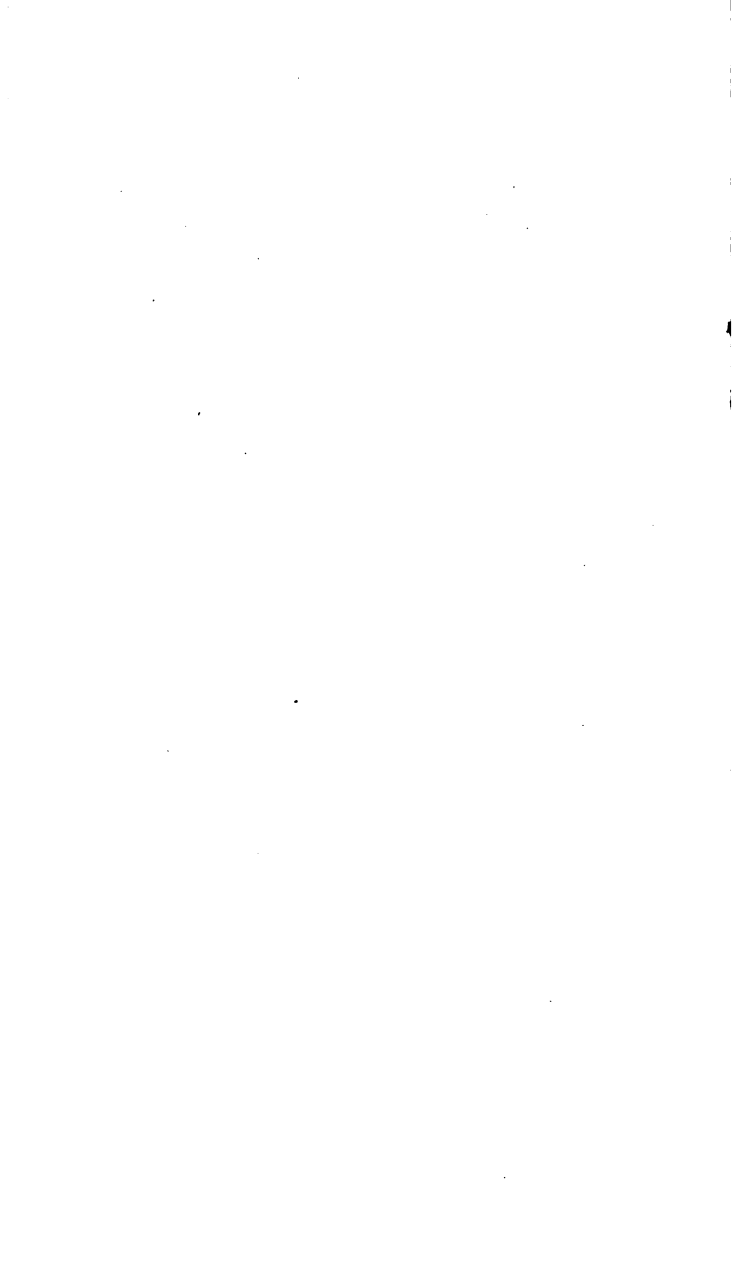
	86°		87°		88°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.86126	10.13874	9.87711	10.12289	9.89281	10.10719	60
1	86153	13847	87738	12262	89307	10693	59
2	86179	13821	87764	12236	89333	10667	58
3	86206	13794	87790	12210	89359	10641	57
4	86232	13768	87817	12183	89385	10615	56
5	86259	13741	87843	12157	89411	10589	55
6	86285	13715	87869	12131	89437	10563	54
7	86312	13688	87895	12105	89463	10537	53
8	86339	13662	87922	12078	89489	10511	52
9	86365	13635	87948	12052	89515	10485	51
10	9.86392	10.13608	9.87974	10.12026	9.89541	10.10459	50
11	86418	13582	88000	12000	89567	10433	49
12	86445	13555	88027	11973	89593	10407	48
13	86471	13529	88053	11947	89619	10381	47
14	86498	13502	88079	11921	89645	10355	46
15	86524	13476	88105	11895	89671	10329	45
16	86551	13449	88131	11869	89697	10303	44
17	86577	13423	88158	11842	89723	10277	43
18	86603	13397	88184	11816	89749	10251	42
19	86630	13370	88210	11790	89775	10225	41
20	9.86656	10.13344	9.88236	10.11764	9.89801	10.10199	40
21	86683	13317	88262	11738	89827	10173	39
22	86709	13291	88289	11711	89853	10147	38
23	86736	13264	88315	11685	89879	10121	37
24	86762	13238	88341	11659	89905	10095	36
25	86789	13211	88367	11633	89931	10069	35
26	86815	13185	88393	11607	89957	10043	34
27	86842	13158	88420	11580	89983	10017	33
28	86868	13132	88446	11554	90009	9991	32
29	86894	13106	88472	11528	90035	9965	31
30	9.86921	10.13079	9.88498	10.11502	9.90061	10.09939	30
31	86947	13053	88524	11476	90086	99914	29
32	86974	13026	88550	11450	90112	99888	28
33	87000	13000	88577	11423	90138	99862	27
34	87027	12973	88603	11397	90164	99836	26
35	87053	12947	88629	11371	90190	99810	25
36	87079	12921	88655	11345	90216	99784	24
37	87106	12894	88681	11319	90242	99758	23
38	87132	12868	88707	11293	90268	99732	22
39	87158	12842	88733	11267	90294	99706	21
40	9.87185	10.12815	9.88759	10.11241	9.90320	10.09680	20
41	87211	12789	88786	11214	90346	99654	19
42	87238	12762	88812	11188	90371	99629	18
43	87264	12736	88838	11162	90397	99603	17
44	87290	12710	88864	11136	90423	99577	16
45	87317	12683	88890	11110	90449	99551	15
46	87343	12657	88916	11084	90475	99525	14
47	87369	12631	88942	11058	90501	99499	13
48	87396	12604	88968	11032	90527	99473	12
49	87422	12578	88994	11006	90553	99447	11
50	9.87448	10.12552	9.89020	10.10980	9.90578	10.09422	10
51	87475	12525	89046	10954	90604	99396	9
52	87501	12499	89073	10927	90630	99370	8
53	87527	12473	89099	10901	90656	99344	7
54	87554	12446	89125	10875	90682	99318	6
55	87580	12420	89151	10849	90708	99292	5
56	87606	12394	89177	10823	90734	99266	4
57	87633	12367	89203	10797	90759	99241	3
58	87659	12341	89229	10771	90785	99215	2
59	87685	12315	89255	10745	90811	99189	1
60	87711	12289	89281	10719	90837	99163	0
	53°		52°		51°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	39°		40°		41°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.90837	10.09163	9.92381	10.07619	9.93916	10.06084	60
1	90863	09187	92407	07593	93942	06058	59
2	90889	09111	92433	07567	93967	06033	58
3	90914	09086	92458	07542	93993	06007	57
4	90940	09060	92484	07516	94018	05982	56
5	90966	09034	92510	07490	94044	05956	55
6	90992	09008	92535	07465	94069	05931	54
7	91018	08982	92561	07439	94095	05905	53
8	91043	08957	92587	07413	94120	05880	52
9	91069	08931	92612	07388	94146	05854	51
10	9.91095	10.08905	9.92638	10.07362	9.94171	10.05829	50
11	91121	08879	92663	07337	94197	05803	49
12	91147	08853	92689	07311	94222	05778	48
13	91173	08828	92715	07285	94248	05752	47
14	91198	08802	92740	07260	94273	05727	46
15	91224	08776	92766	07234	94299	05701	45
16	91250	08750	92792	07208	94324	05676	44
17	91276	08724	92817	07183	94350	05650	43
18	91301	08699	92843	07157	94375	05625	42
19	91327	08673	92868	07132	94401	05599	41
20	9.91353	10.08647	9.92894	10.07106	9.94426	10.05574	40
21	91379	08621	92920	07080	94452	05548	39
22	91404	08596	92945	07055	94477	05523	38
23	91430	08570	92971	07029	94503	05497	37
24	91456	08544	92996	07004	94528	05472	36
25	91482	08518	93022	06978	94554	05446	35
26	91507	08493	93048	06953	94579	05421	34
27	91533	08467	93073	06927	94604	05396	33
28	91559	08441	93099	06901	94630	05370	32
29	91585	08415	93124	06876	94655	05345	31
30	9.91610	10.08390	9.93150	10.06850	9.94681	10.05319	30
31	91636	08364	93175	06825	94706	05294	29
32	91662	08338	93201	06799	94732	05268	28
33	91688	08312	93227	06773	94757	05243	27
34	91713	08287	93252	06748	94783	05217	26
35	91739	08261	93278	06722	94808	05192	25
36	91765	08235	93303	06697	94834	05166	24
37	91791	08209	93329	06671	94859	05141	23
38	91816	08184	93354	06646	94884	05116	22
39	91842	08158	93380	06620	94910	05090	21
40	9.91868	10.08132	9.93406	10.06594	9.94985	10.05065	20
41	91893	08107	93431	06569	94961	05039	19
42	91919	08081	93457	06543	94986	05014	18
43	91945	08055	93482	06518	95012	04988	17
44	91971	08029	93508	06492	95037	04963	16
45	91996	08004	93533	06467	95062	04938	15
46	92022	07978	93559	06441	95088	04912	14
47	92048	07952	93584	06416	95113	04887	13
48	92073	07927	93610	06390	95139	04861	12
49	92099	07901	93636	06364	95164	04836	11
50	9.92125	10.07875	9.93661	10.06339	9.95190	10.04810	10
51	92150	07850	93687	06313	95215	04785	9
52	92176	07824	93712	06288	95240	04760	8
53	92202	07798	93738	06262	95266	04734	7
54	92227	07773	93763	06237	95291	04709	6
55	92253	07747	93789	06211	95317	04683	5
56	92279	07721	93814	06186	95342	04658	4
57	92304	07696	93840	06160	95368	04632	3
58	92330	07670	93865	06135	95393	04607	2
59	92356	07644	93891	06109	95418	04582	1
60	92381	07619	93916	06084	95444	04556	0
	50°		49°		48°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	

TABLE XXI.—LOG. TANGENTS AND COTANGENTS.

	42°		48°		44°		
	Tan	Cotan	Tan	Cotan	Tan	Cotan	
0	9.95444	10.04556	9.96966	10.03034	9.98484	10.01516	60
1	95469	04531	96991	03009	98509	01491	59
2	95496	04506	97016	02984	98534	01466	58
3	95520	04480	97042	02958	98560	01440	57
4	95545	04455	97067	02933	98585	01415	56
5	95571	04429	97092	02908	98610	01390	55
6	95596	04404	97118	02882	98635	01365	54
7	95622	04378	97143	02857	98661	01339	53
8	95647	04353	97168	02832	98686	01314	52
9	95672	04328	97193	02807	98711	01289	51
10	9.95698	10.04302	9.97219	10.02781	9.98737	10.01263	50
11	95723	04277	97244	02756	98762	01238	49
12	95748	04252	97269	02731	98787	01213	48
13	95774	04226	97295	02705	98812	01188	47
14	95799	04201	97320	02680	98838	01162	46
15	95825	04175	97345	02655	98863	01137	45
16	95850	04150	97371	02629	98888	01112	44
17	95875	04125	97396	02604	98913	01087	43
18	95901	04099	97421	02579	98939	01061	42
19	95926	04074	97447	02553	98964	01036	41
20	9.95952	10.04048	9.97472	10.02528	9.98989	10.01011	40
21	95977	04023	97497	02503	99015	00985	39
22	96002	03998	97523	02477	99040	00960	38
23	96028	03972	97548	02452	99065	00935	37
24	96053	03947	97573	02427	99090	00910	36
25	96078	03922	97598	02402	99116	00884	35
26	96104	03896	97624	02376	99141	00859	34
27	96129	03871	97649	02351	99166	00834	33
28	96155	03845	97674	02326	99191	00809	32
29	96180	03820	97700	02300	99217	00783	31
30	9.96205	10.03795	9.97725	10.02275	9.99242	10.00758	30
31	96231	03769	97750	02250	99267	00733	29
32	96256	03744	97776	02224	99293	00707	28
33	96281	03719	97801	02199	99318	00682	27
34	96307	03693	97826	02174	99343	00657	26
35	96332	03668	97851	02149	99368	00632	25
36	96357	03643	97877	02123	99394	00606	24
37	96383	03617	97902	02098	99419	00581	23
38	96408	03592	97927	02073	99444	00556	22
39	96433	03567	97953	02047	99469	00531	21
40	9.96459	10.03541	9.97978	10.02022	9.99495	10.00505	20
41	96484	03516	98003	01997	99520	00480	19
42	96510	03490	98029	01971	99545	00455	18
43	96535	03465	98054	01946	99570	00430	17
44	96560	03440	98079	01921	99596	00404	16
45	96586	03414	98104	01896	99621	00379	15
46	96611	03389	98130	01870	99646	00354	14
47	96636	03364	98155	01845	99672	00328	13
48	96662	03338	98180	01820	99697	00303	12
49	96687	03313	98206	01794	99722	00278	11
50	9.96712	10.03288	9.98231	10.01769	9.99747	10.00253	10
51	96738	03262	98256	01744	99773	00227	9
52	96763	03237	98281	01719	99798	00202	8
53	96788	03212	98307	01693	99823	00177	7
54	96814	03186	98332	01668	99848	00152	6
55	96839	03161	98357	01643	99874	00126	5
56	96864	03136	98383	01617	99899	00101	4
57	96890	03110	98408	01592	99924	00076	3
58	96915	03085	98433	01567	99949	00051	2
59	96940	03060	98458	01542	99975	00025	1
60	96966	03034	98484	01516	10.00000	00000	0
	47°		46°		45°		
	Cotan	Tan	Cotan	Tan	Cotan	Tan	





APPENDIX.

THE TRANSITION CURVE.

The true transition curve is a spiral whose radius of curvature at the origin, A , is infinity, and at any point on the curve is inversely proportional to the distance of that point from A ; or, the degree of curvature is directly proportional to this distance. The degree of curvature will therefore have a constant increase per foot.

Let n = this increase in minutes,
 d = the distance of any point from A ,
and δ = degree of curvature at distance d ;

then
$$\delta = \frac{nd}{60}, \quad (1)$$

and
$$d = \frac{60 \delta}{n}. \quad (2)$$

Now, since the curvature increases uniformly from 0 to δ in the distance d , it is evident that the total angle turned will be only half that turned by a δ° curve d feet in length. Therefore the total angle turned by the spiral in the distance d will be $\frac{60 \delta d}{200}$ (expressed in minutes).

If in Fig. 1 B be the point where the degree of curvature becomes δ , then

$$AB = d,$$

and
$$BGF = \frac{60 \delta d}{200}. \quad (3)$$

Substituting the value of δ from (1), we have

$$BGF = \frac{nd^2}{200}. \quad (4)$$

By (5) and (6) the spiral may be laid out with the transit using (5) for deflections from the tangent and (6) for turning tangent from any chord. If there be no obstacle in the line of sight, and the terminating spiral be run backward, we need nothing more. But it may be necessary to set some intermediate point, as B , and continue from that point by deflections from the tangent BK ; and it is generally desirable to run the terminating spiral with the transit set at its junction with the central curve. It is therefore necessary to find a general expression for the deflection *from any point on the spiral to any other point on the spiral*.

From (5) we have

$$\sin BAF = \frac{.00029 nd^2}{600}, \quad (7)$$

since $.00029 = \text{sine of } 1'.$

Then if $d' = BC$, that is any distance beyond B , we have also

$$\sin CAF = \frac{.00029 n(d + d')^2}{600}. \quad (8)$$

Hence we have for the ordinates FB and CE , by regarding the curves AB and AC as equal to the chords of the same,

$$FB = \frac{.00029 nd^3}{600}, \quad (9)$$

$$CE = \frac{.00029 n(d + d')^3}{600}. \quad (10)$$

$$\text{Then } CH = CE - FB = \frac{.00029 n(3d^2d' + 3dd'^2 + d'^3)}{600}, \quad (11)$$

$$\text{and } \frac{CH}{d'} = \sin CBH = \frac{.00029 n(3d^2 + 3dd' + d'^2)}{600}, \quad (12)$$

$$\text{or } CBH = \frac{n(3d^2 + 3dd' + d'^2)}{600}. \quad (13)$$

$$\text{But } CBK = CBH - KBH = CBH - BGF = CBH - \frac{nd^2}{200}.$$

$$\text{Therefore } CBK = \frac{n(3dd' + d'^2)}{600} = \frac{nd'^2}{600} + d \frac{nd'}{200}. \quad (14)$$

To obtain an expression for the angle BCK , we have from (4)

$$CDE = \frac{n(d + d')^2}{200}, \quad (15)$$

and since

$$BCK = CDE - CBH, \\ BCK = \frac{n(3dd' + 2d'^2)}{600} = \frac{nd'^2}{300} + d' \frac{nd'}{200}. \quad (16)$$

Eqs. (14) and (16) may be put into the following forms:—

$$CBK = \left(\frac{nd}{60} \times \frac{1}{2} \times \frac{60d'}{100} \right) + \frac{nd'^2}{600}, \quad (17)$$

$$BCK = \left(\frac{n(d + d')}{60} \times \frac{1}{2} \times \frac{60d'}{100} \right) - \frac{nd'^2}{600}, \quad (18)$$

in which the first term of (17) is the deflection for a distance d' of a circular curve, whose curvature is equal to the curvature of the spiral at distance d (see Eq. 1); and the first term of (18) is the deflection for a distance d' of a circular curve, whose curvature is equal to the curvature of the spiral at distance $d + d'$. Hence the following property:—

The deflection from tangent at any point on the spiral to any other point on the spiral is equal to the deflection of a circular curve for the same distance, whose curvature is equal to the curvature of the spiral at said tangent point, PLUS or MINUS the deflection for an equal distance from the initial point of the spiral, according as the transit is turned TOWARD or FROM the central curve.

To find the length of semi-tangent, T , and external secant, E , we have from (9), since

$$FN = 2FB, \\ FN = O = \frac{.00029nd^3}{300}, \quad (19)$$

in which $d = \frac{1}{2}$ total length of spiral. Therefore if in Fig. 2 L = total length of spiral, V = point of intersection of tangents, P = middle point of circular curve, and I = angle of intersection of tangents, then

$$AV = T = (R + O) \tan \frac{1}{2} I + \frac{1}{2} L, \quad (20)$$

$$\text{and} \quad PV = E = \frac{R + O}{\cos \frac{1}{2} I} - R. \quad (21)$$

It is proposed to call n in these formulas the *number of the spiral*. Thus if $n = 2$, we would designate the spiral as a *number two spiral*; if $n = 3$, a *number three spiral*, etc. n may have any value whatever, either entire or fractional. In practice its value will generally be between 1 and 6.

It will be seen that by this method the transition curve becomes absolutely universal. By varying the value of n a spiral of any length whatever can be fitted to a central curve of any degree. The question of *standard sub-chords*, which are used in a great many systems of treating the transition curve, is entirely eliminated. A transit hub can be set at any point on the curve and deflections may be turned from any point on the curve to any other point with practically the same ease and facility as in the simple curve.

HOW TO LAY OUT A SPIRAL CURVE.

1. The tables which follow will greatly facilitate the work of computing and laying out the spiral. Table I gives the length (L), total angle (A), and central curve offset (O) of a No. 1 spiral for central curves of different degrees. To find the corresponding elements of a spiral of different number it will be observed that L and A vary inversely as the number and O inversely as the square of the number. The number of the spiral should be so chosen that the total angle will not much exceed 15° , as the formula for deflections becomes less accurate for large angles. Table II is a tabulation of Eq. 5 for a No. 1 spiral.

2. Determine by inspection of Table I and the conditions on the ground the number of the spiral to be used in any particular case, and find central curve offset, O , for this spiral.

Calculate semi-tangent by the following formula,

$$T = (R + O) \tan \frac{1}{2} I + \frac{1}{2} L,$$

and locate points of the spiral A and F on each tangent.

3. Set transit at A and by use of Table II turn deflections for all points from A to C . Move transit to C , backsight on

A, and turn twice the angle that was turned at *A*, which will bring transit on tangent at this point. Continue around the central curve to *D* in the usual manner. The transit may then be moved to *F* and the terminating spiral run backward in the same manner as the first spiral was run forward.

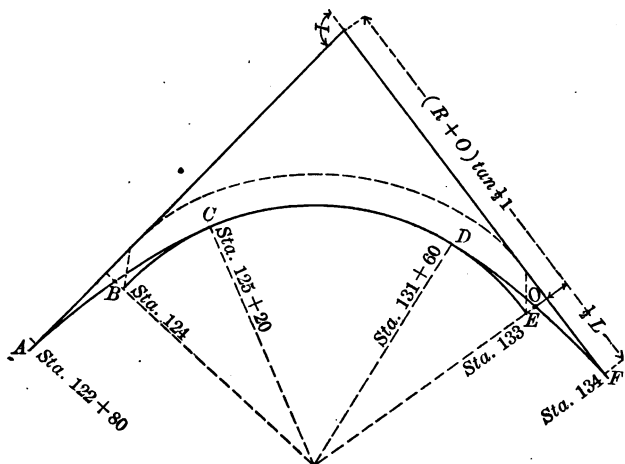


FIG. 3.

4. If desired to run both spirals and central curve continuously from beginning to end, or to turn deflections from intermediate points on either spiral, observe the property of the spiral, stated on page 324.

5. An example will illustrate the application of this property. Suppose it be required to run a 4° curve with No. 1 spirals, and the initial point, *A*, be established at Sta. 122 + 80 as shown in Fig. 3. Table I shows that either spiral will be 240 feet long, and that the initial spiral will connect with the central curve at Sta. 125 + 20. Suppose the other end of the central curve be found at Sta. 131 + 60. The terminating spiral will then unite with the tangent at Sta. 134.

6. Suppose it be desired to set transit points at *B*, Sta. 124, and *E*, Sta. 133, in addition to points *C* and *D* at ends of the

central curve, and run the entire curve continuously. Set transit at *A*, and turn deflections as follows:—

Sta. 123: deflection for 20 feet (by Table II)	0° 00.7'
Sta. 124: deflection for 120 feet (by table)	0° 24.'

7. Move transit to *B*. Backsight on *A* and turn 0° 48' for tangent. Then for deflections from *B* to *C*, since the spiral has attained a curvature of 2° per 100 feet at *B*, we have, according to the property stated above,

Sta. 125: deflection for 100 feet, 2° curve	1° 00.'
Plus deflection for 100 feet spiral (by table)	16.7'
Total	1° 16.7'

Sta. 125 + 20: deflection for 120 feet, 2° curve	1° 12.'
Plus deflection for 120 feet spiral (by table)	24.'
Total	1° 36.'

8. Then move transit to *C*. Backsight on *B*, and to turn tangent, since curvature has become 4° at *C*,

Deflection for 120 feet, 4° curve	2° 24.'
Minus deflection for 120 feet spiral (by table)	24.'
Total	2° 00.'

9. Circular curve is then run to *D*. Next move transit to *D* and set on tangent at this point. We then have for deflections from *D* to *F*, since curvature is here 4°,

Sta. 132: deflection for 40 feet, 4° curve	0° 48.'
Minus deflection for 40 feet spiral (by table)	02.7'
Total	0° 45.3'

Sta. 133: deflection for 140 feet, 4° curve	2° 48.'
Minus deflection for 140 feet spiral (by table)	32.7'
Total	2° 15.3'

10. Move transit to *E*. Backsight on *D*, and to turn tangent, since spiral has a curvature of 1° 40' at this point, we have

Deflection for 140 feet, 1° 40' curve	1° 10.'
Plus deflection for 140 feet spiral (by table)	32.7'
Total	1° 42.7'

Then, to finish curve, we have

Deflection for 100 feet, $1^{\circ} 40'$ curve	$0^{\circ} 50.'$
Minus deflection for 100 feet spiral (by table)	<u>$16.7'$</u>
Total	$0^{\circ} 33.3'$

11. By moving transit to *F*, and backsighting upon *E*, we have for turning on final tangent

Deflection for 100 feet spiral (by table)	$0^{\circ} 16.7'$
---	-------------------

EXAMPLES.

1. Intersection of two tangents, Sta. 127 + 65.2; intersection angle $I = 35^{\circ} 24'$.

Connect tangents with a 6° curve ($R = 955$) terminating in a No. 2 spiral. By reference to Table I we find

$$L = 180 \text{ feet}; A = 5^{\circ} 24'; O = 1.41 \text{ feet.}$$

$$\therefore T = (R + O) \tan \frac{1}{2} I + \frac{1}{2} L = 395.2 \text{ feet.}$$

Beginning of spiral, $BS = \text{Sta. } 123 + 70.$

Beginning of central curve, $BC = \text{ " } 125 + 50.$

End of central curve, $EC = \text{ " } 129 + 60.$

End of spiral, $ES = \text{ " } 131 + 40.$

Set transit at *BS*, Sta. 123 + 70

Deflection to Sta. 124 $= 0^{\circ} 03.'$

Deflection to Sta. 125 $= 0^{\circ} 56.4'$

Deflection to Sta. 125 + 50 $= 1^{\circ} 48.'$

Move transit to Sta. 125 + 50. Backsight on Sta. 123 + 70 and turn $3^{\circ} 36'$ for tangent. Run central curve to Sta. 129 + 60 in usual manner. Move transit to this point and set on tangent in usual way. Then

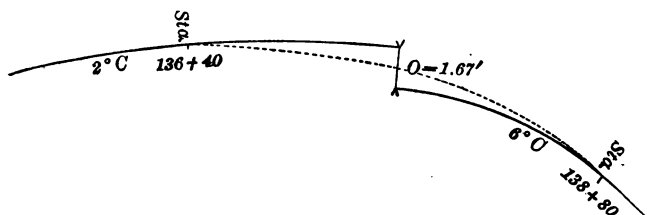
Deflection to Sta. 130 $= 1^{\circ} 06.6'$

Deflection to Sta. 131 $= 3^{\circ} 06.6'$

Deflection to Sta. 131 + 40 $= 3^{\circ} 36.'$

Move transit to Sta. 131 + 40. Backsight on Sta. 129 + 60 and turn on final tangent by turning $1^{\circ} 48'$.

2. Illustrating the use of the spiral as a transition between the branches of a compound curve. A 2° curve compounding to a 6° is to be connected by a No. 1 spiral.



In this case the length of the spiral and offset between curves produced is the same as for a 4° ($6^\circ - 2^\circ$) curve. $L = 240$ feet, $O = 1.67$ feet.

Deflections from Sta. 136 + 40 to Sta. 138 + 80 would be deflections for a 2° curve *plus* tabular deflections for spiral, and deflections from Sta. 138 + 80 to Sta. 136 + 40 would be deflections for a 6° curve *minus* tabular deflections for spiral, as follows: —

Transit at Sta. 136 + 40 :

Deflection to Sta. 137	$= 0^\circ 42.'$
Deflection to Sta. 138	$= 2^\circ 18.7'$
Deflection to Sta. 138 + 80	$= 4^\circ 00.'$

Transit at Sta. 138 + 80 :

Deflection to Sta. 138	$= 2^\circ 13.3'$
Deflection to Sta. 137	$= 4^\circ 30.'$
Deflection to Sta. 136 + 40	$= 5^\circ 36.'$

TABLE I.

ELEMENTS OF A NO. 1 SPIRAL.

L = Length of spiral.*A* = Total angle turned by spiral.*O* = Central curve offset.*L* and *A* vary inversely as the number of spiral.*O* varies inversely as square of the number.

Deg.	<i>L</i>	<i>A</i>	<i>O</i>	Deg.	<i>L</i>	<i>A</i>	<i>O</i>
2° 00'	120	1° 12' 00"	.21	7° 10'	430	15° 24' 30"	9.61
10	130	1 24 30	.27	20	440	16 08 00	10.29
20	140	1 38 00	.33	30	450	16 52 30	11.01
30	150	1 52 30	.41	40	460	17 38 00	11.76
40	160	2 08 00	.49	50	470	18 24 30	12.55
50	170	2 24 30	.59	8 00	480	19 12 00	13.36
3 00	180	2 42 00	.70	10	490	20 00 30	14.22
10	190	3 00 30	.83	20	500	20 50 00	15.10
20	200	3 20 00	.97	30	510	21 40 30	16.03
30	210	3 40 30	1.12	40	520	22 32 00	16.99
40	220	4 02 00	1.29	50	530	23 24 30	17.99
50	230	4 24 30	1.47	9 00	540	24 18 00	19.03
4 00	240	4 48 00	1.67	10	550	25 12 30	20.10
10	250	5 12 30	1.89	20	560	26 08 00	21.22
20	260	5 38 00	2.12	30	570	27 04 30	22.38
30	270	6 04 30	2.38	40	580	28 02 00	23.58
40	280	6 32 00	2.65	50	590	29 00 30	24.82
50	290	7 00 30	2.95	10 00	600	30 00 00	26.10
5 00	300	7 30 00	3.26	30	630	33 04 30	30.21
10	310	8 00 30	3.60	11 00	660	36 18 00	34.74
20	320	8 32 00	3.96	30	690	39 40 30	39.69
30	330	9 04 30	4.34	12 00	720	43 12 00	45.10
40	340	9 38 00	5.75	30	750	46 52 30	50.98
50	350	10 12 30	5.18	13 00	780	50 42 00	57.34
6 00	360	10 48 00	5.64	14 00	840	58 48 00	61.62
10	370	11 24 30	6.12	15 00	900	67 30 00	88.09
20	380	12 02 00	6.63	16 00	960	76 48 00	106.91
30	390	12 40 30	7.17	17 00	1020	86 42 00	128.23
40	400	13 20 00	7.73	18 00	1080	97 12 00	152.22
50	410	14 00 30	8.33	19 00	1140	108 18 00	179.02
7 00	420	14 42 00	8.95	20 00	1200	120 00 00	208.80

TABLE II.

DEFLECTIONS OF A NO. 1 SPIRAL FOR DIFFERENT VALUES OF d .

(Deflections for spiral of different number in direct proportion.)

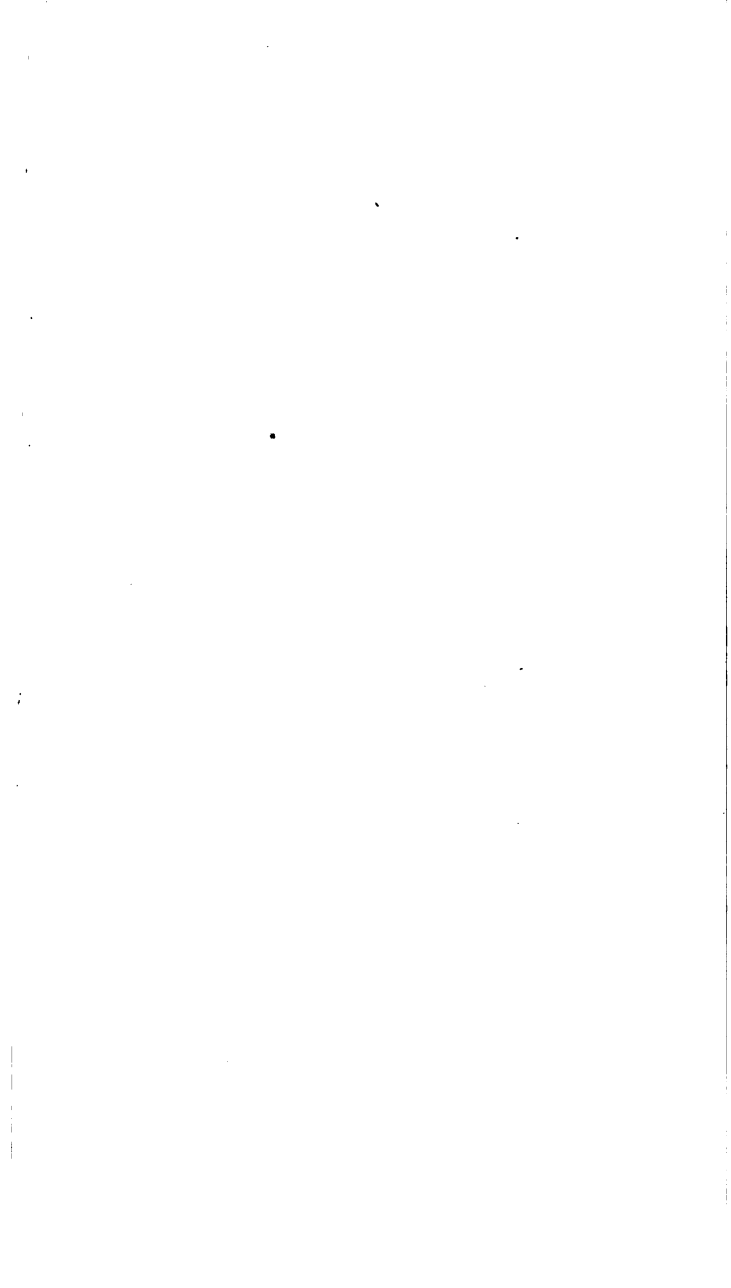
d	$\frac{d^2}{600}$	d	$\frac{d^2}{600}$	d	$\frac{d^2}{600}$	d	$\frac{d^2}{600}$
0	0.0	50	4.1	100	16.7	150	37.5
1	0.0	51	4.3	101	17.0	151	38.0
2	0.0	52	4.5	102	17.3	152	38.5
3	0.0	53	4.7	103	17.7	153	39.0
4	0.0	54	4.9	104	18.0	154	39.5
5	0.0	55	5.0	105	18.4	155	40.0
6	0.1	56	5.2	106	18.7	156	40.6
7	0.1	57	5.4	107	19.1	157	41.1
8	0.1	58	5.6	108	19.4	158	41.6
9	0.1	59	5.8	109	19.8	159	42.1
10	0.2	60	6.0	110	20.2	160	42.7
11	0.2	61	6.2	111	20.5	161	43.2
12	0.2	62	6.4	112	20.9	162	43.7
13	0.3	63	6.6	113	21.3	163	44.3
14	0.3	64	6.8	114	21.7	164	44.8
15	0.4	65	7.0	115	22.0	165	45.4
16	0.4	66	7.3	116	22.4	166	45.9
17	0.5	67	7.5	117	22.8	167	46.5
18	0.5	68	7.7	118	23.2	168	47.0
19	0.6	69	7.9	119	23.6	169	47.6
20	0.7	70	8.2	120	24.0	170	48.2
21	0.7	71	8.4	121	24.4	171	48.7
22	0.8	72	8.6	122	24.8	172	49.3
23	0.9	73	8.9	123	25.2	173	49.9
24	1.0	74	9.1	124	25.6	174	50.5
25	1.0	75	9.4	125	26.0	175	51.0
26	1.1	76	9.6	126	26.5	176	51.6
27	1.2	77	9.9	127	26.9	177	52.2
28	1.3	78	10.1	128	27.3	178	52.8
29	1.4	79	10.4	129	27.7	179	53.4
30	1.5	80	10.7	130	28.2	180	54.0
31	1.6	81	11.0	131	28.6	181	54.6
32	1.7	82	11.2	132	29.0	182	55.2
33	1.8	83	11.5	133	29.5	183	55.8
34	1.9	84	11.8	134	29.9	184	56.4
35	2.0	85	12.0	135	30.4	185	57.0
36	2.2	86	12.3	136	30.8	186	57.7
37	2.3	87	12.6	137	31.3	187	58.3
38	2.4	88	12.9	138	31.7	188	58.9
39	2.5	89	13.2	139	32.2	189	59.5
40	2.7	90	13.5	140	32.7	190	60.2
41	2.8	91	13.8	141	33.1	191	60.8
42	2.9	92	14.1	142	33.6	192	61.4
43	3.1	93	14.4	143	34.1	193	62.1
44	3.2	94	14.7	144	34.6	194	62.7
45	3.4	95	15.0	145	35.0	195	63.4
46	3.5	96	15.4	146	35.5	196	64.0
47	3.7	97	15.7	147	36.0	197	64.7
48	3.8	98	16.0	148	36.5	198	65.3
49	4.0	99	16.3	149	37.0	199	66.0

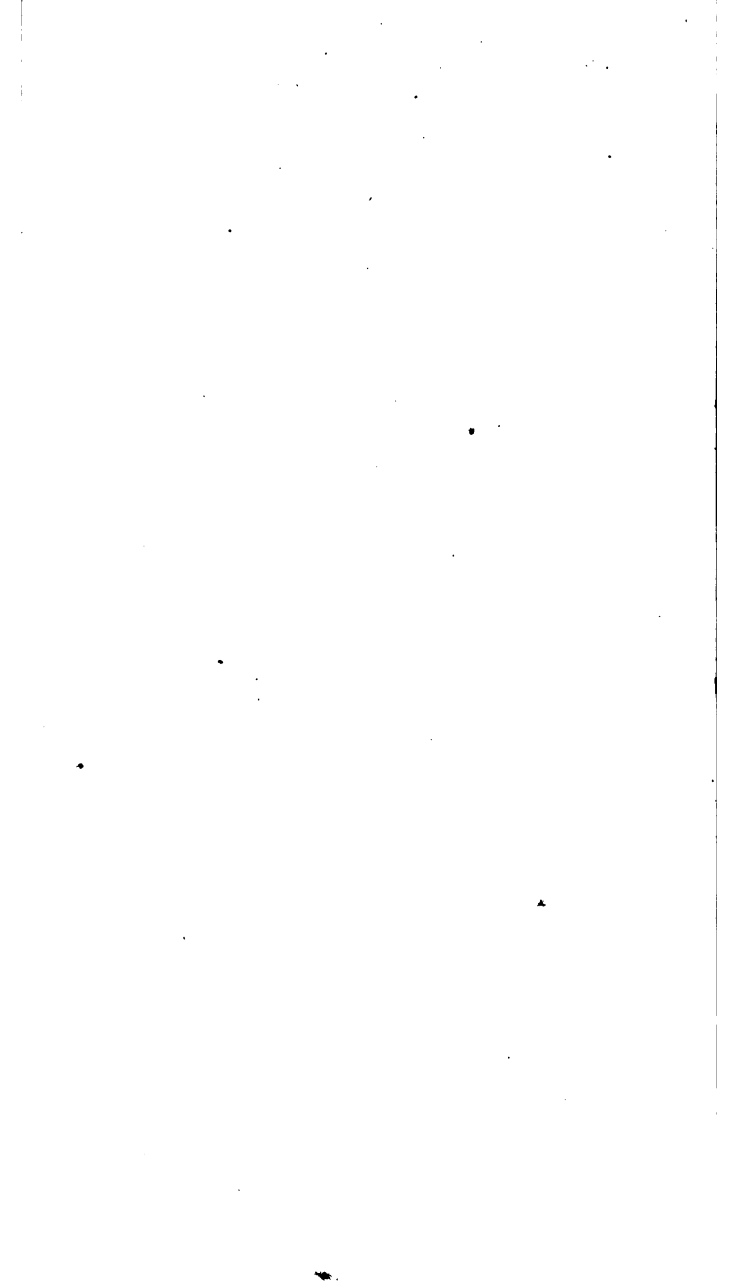
TABLE II. — *Continued.*

d	$\frac{d^3}{600}$	d	$\frac{d^3}{600}$	d	$\frac{d^3}{600}$	d	$\frac{d^3}{600}$
200	66.7	240	96.0	280	130.7	320	170.7
201	67.3	241	96.8	281	131.6	321	171.7
202	68.0	242	97.6	282	132.5	322	172.8
203	68.7	243	98.4	283	133.5	323	173.9
204	69.4	244	99.2	284	134.4	324	175.0
205	70.1	245	100.0	285	135.4	325	176.0
206	70.7	246	100.9	286	136.3	326	177.1
207	71.4	247	101.7	287	137.3	327	178.2
208	72.1	248	102.5	288	138.2	328	179.3
209	72.8	249	103.3	289	139.2	329	180.4
210	73.5	250	104.2	290	140.2	330	181.5
211	74.2	251	105.0	291	141.1	331	182.6
212	74.9	252	105.8	292	142.1	332	183.7
213	75.6	253	106.7	293	143.1	333	184.8
214	76.3	254	107.5	294	144.1	334	185.9
215	77.0	255	108.4	295	145.0	335	187.0
216	77.8	256	109.2	296	146.0	336	188.2
217	78.5	257	110.1	297	147.0	337	189.3
218	79.2	258	110.9	298	148.0	338	190.4
219	79.8	259	111.8	299	149.0	339	191.5
220	80.7	260	112.7	300	150.0	340	192.7
221	81.4	261	113.5	301	151.0	341	193.8
222	82.1	262	114.4	302	152.0	342	194.9
223	82.9	263	115.3	303	153.0	343	196.1
224	83.6	264	116.2	304	154.0	344	197.2
225	84.4	265	117.0	305	155.0	345	198.4
226	85.1	266	117.8	306	156.1	346	199.6
227	85.9	267	118.8	307	157.1	347	200.7
228	86.6	268	119.7	308	158.1	348	201.8
229	87.4	269	120.6	309	159.1	349	203.0
230	88.2	270	121.5	310	160.2	350	204.2
231	88.9	271	122.4	311	161.2	351	205.3
232	89.7	272	123.3	312	162.2	352	206.5
233	90.5	273	124.2	313	163.3	353	207.7
234	91.3	274	125.1	314	164.3	354	208.9
235	92.0	275	126.0	315	165.4	355	210.0
236	92.8	276	127.0	316	166.4	356	211.2
237	93.6	277	127.9	317	167.5	357	212.4
238	94.4	278	128.8	318	168.5	358	213.6
239	95.2	279	129.7	319	169.6	359	214.8









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